THE GLASS INDUSTRY

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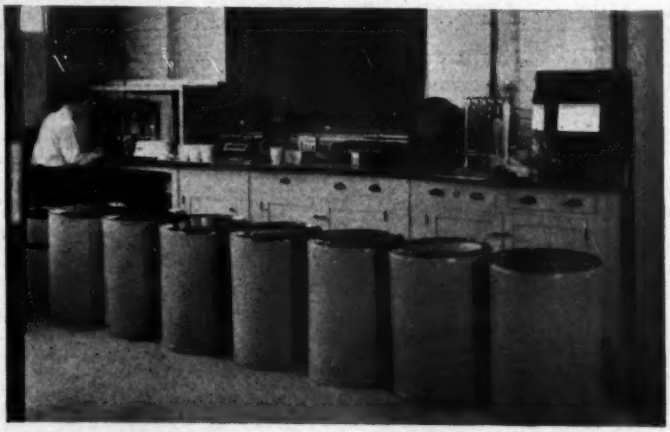
ARMSTRONG'S GLASS RESEARCH AIDED BY VARIED INTERESTS

Inter-relationship between glass and other products often directly benefits glass laboratory activities.

A tour of the Research Laboratory of the Armstrong Cork Company at Lancaster, Pa., is illuminating for a number of reasons to a visitor interested primarily in the glass industry. But three impressions stand out—first, the extent of the Laboratory's specific activities in the glass field; second, the size of the Company's whole research and development program; and, third, the inter-relationship between glass research and the work being done on other products and in other fields.



General view of the batch room and inspection bench.

Armstrong's list of normal products numbers more than 360. Besides a general line of glass containers, insulators, and other products of glass, the Company manufactures closures of cork, metal and plastics, as well as crown caps; insulating fire brick, corkboard and other insulating materials; linoleum, asphalt tile, and other resilient floorings; wall coverings; acoustical materials; textile roll coverings; shoe materials; gaskets, packings and seals; and numerous industrial specialties. In addition, the Company distributes Foamglas, glass wool insulation, and several other products used in the fields in which Armstrong is active.

Many of the Company's regular products have found important war applications and, since before Pearl Harbor, the Company also has been engaged in the munitions business, turning out substantial quantities of such unfamiliar (i.e., to the Company) items as shells, cartridge cases, rocket parts, magnesium incendiary bomb bodies, bomb cluster adapters, aircraft parts and assemblies, and concealment materials.

Some people outside of the glass industry still are surprised to find Armstrong—which is probably best known as a manufacturer of linoleum and other resilient floor coverings—engaged in making glass. But to the Company its entry into the glass business seemed a very natural step in its normal progress and growth. Since its inception in Pittsburgh in 1860, the firm has been producing cork bottle stoppers. Many years ago it added closures of other kinds to its line, and then Armstrong reasoned that it would be logical to have a complete glass packaging service to offer to its closure customers. Accordingly, it purchased, early in 1938, the century-old Whitall-Tatum Company, with plants located at Millville and Keyport, N. J., and with sand deposits near Millville. Later the same year Armstrong acquired the Hart Glass Manufacturing Company of Dunkirk, Indiana, which had been in business for 59 years. Armstrong is operating two glass plants, at Millville and at Dunkirk. Several years ago the Company moved all of its cork bottle stopper operations to the former Whitall-Tatum plant at Keyport.

Entry into full-scale glass research was likewise a logical and relatively simple step for Armstrong's Research Laboratory, with its extensive background of experience with closures and other products. By its very nature, this work with closures had made the laboratory people familiar with certain phases of the glass container field. Armstrong has been a strong believer in research for years, and the wide diversification of its products is reflected in the size and scope of its Laboratory.

A sizable space in one of the Laboratory buildings is devoted to experimental melting, annealing and other studies, conducted by a staff of six people. This section

A view of a furnace after it has been loaded with batches in porcelain crucibles. The dark crucible is mullite-filled and is used to center the group.

is now virtually a pilot plant. There is ample space for the installation of additional equipment.

Experimental melts are made in two gas-fired furnaces, each with a capacity of seven crucibles. One furnace is run in the morning and the other in the afternoon. The furnaces are cylindrical, 42 inches in diameter and 31 inches high, of a design developed in the Armstrong Laboratory. They are fired by four tangentially placed burners. The air-gas ratio is controlled at one point, from which the mixture is led to all four burners. The furnaces are charged from the top, the porcelain crucibles containing the batch being accurately positioned in the furnace so that all will have the same thermal history. The furnaces can easily be heated to 2600° F. in one hour, without injury to the crucibles.

After the furnace is charged, a refractory lid with a central hole is carefully centered upon it. The opening serves as the escape vent for the gases and also permits frequent observation of all of the crucibles. The furnaces are hooded. Temperature is controlled by means of a radiation pyrometer sighted into a target tube inserted in the sidewall of each furnace. Additional pyrometers can be mounted on the rim of the hood and sighted through the opening in the lid of the furnace on specific glasses. A permanent record of each melt is kept on a temperature recorder chart on which the predetermined firing schedule is drawn and followed. Several firing schedules have been developed for experimental work. The furnaces are operated from the control panel by means of a motor drive connected to the air valve at the regulator. A large-scale manometer mounted on the wall near the furnaces indicates the air pressure. The atmosphere in the furnaces can be accurately controlled, from strongly reducing to strongly oxidizing. Uniform temperature and atmospheric conditions can be maintained throughout the furnaces so that all the crucibles receive the same treatment. During the course of the melt, frequent surveys are made of the surface temperature of the glass in the various crucibles with an optical pyrometer.

Counting the seeds in the annealed slabs, with side illumination from a fluorescent lamp against a dark background.

The crucibles are removed from the furnace one at a time by means of tongs inserted through the opening in the lid. The glass is cast as slabs in iron molds that have been heated to the required temperature. For reproducible results, the timing of the pouring is critical; and a system of electrical signals is used to pace the operator.

There are two gas-fired muffle ovens—one for each furnace—in which the plates are annealed. Indicating pyrometers are attached to the base plates of the molds and to both annealing ovens. The glass is annealed under conditions which closely duplicate those in the plant lehrs.

After annealing, the glass slabs are inspected under a polariscope for strain; seed counts are made to determine the degree of fining; and the color is studied under a uniform light source that matches the "overcast northern sky" of the old-time glass makers, and also by means of a recording photoelectric spectrophotometer.

Experimental melts are made to test batch materials from various sources of supply, to make composition surveys with respect to specific problems, to

Pulling a crucible at the completion of a melt.

study color development, to test the effectiveness of different fining agents, to devise formulae that will melt at lower temperatures and that will have improved working properties, and to study other problems of glass manufacture. Armstrong conducts extensive studies of the chemical durability of glass, under accurately controlled conditions.[1] For this work a special glass still is used in the preparation of doubly distilled water of very low electrical conductivity. An autoclave, in which the pressure or temperature schedule is controlled, is used in these accelerated durability tests. With pharmaceutical, liquor and food containers representing a considerable portion of its glass business, Armstrong pays particular attention to the control and improvement of durability.

X-ray check on the fit of a plastic and an aluminum closure on the finish of an 8 oz. prescription bottle.

In another building there is a chemical laboratory devoted exclusively to the analysis of glass, with a research analyst in charge. The facilities and the collaboration of the Organic and General Chemical Sections of the Laboratory also are available to the Glass Section. Suitable petrographic equipment makes possible the microscopic examination of batch materials, and of devitrification and weathering products that may occur in glass.

Armstrong for some time has been conducting studies of the tempering of glass containers, with better control of strain distribution as the objective. These studies, of course, are of particular importance in modern packaging.

Because, in the final analysis, a glass container is only as good as the sealing finish which controls the fit of the closures and the pouring characteristics, the Armstrong Laboratory pays a great deal of attention to this detail. One of the ways in which finish is studied is by means of a contour projector which throws a shadow-image of a bottle upon a scaled screen, usually with a magnification of ten diameters. By this method, variations in the contour can readily be studied, and the dimensions of the finish can be measured more accurately than with calipers. X-ray photographs also are used to study the conformation of the closure in place on the finish.

Naturally, the Glass Section of the Laboratory operates in close cooperation with the Closure Section, for closure performance determines, to an important degree, the success of a glass container. The Closure Section makes thousands of tests to determine the right closure and the right combination of closure and liner for particular products. Many tests are made, too, to determine what type of liner facing, whether metal foil or other material, should be used to resist the chemical action of the contents.

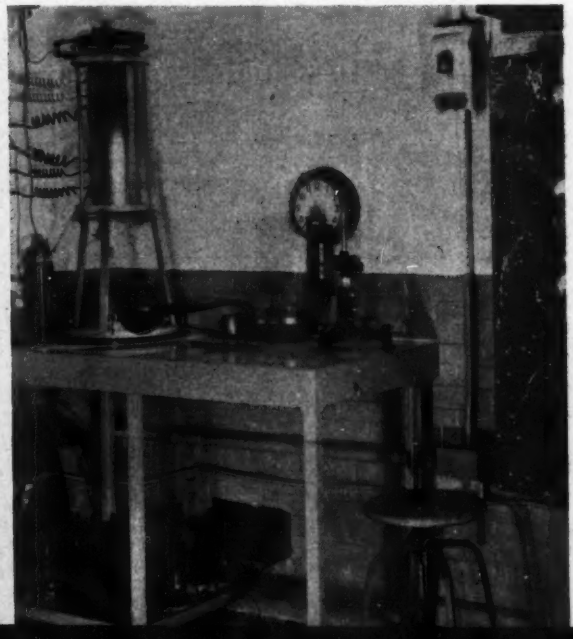
A Glass Applications Section studies the relationship between glass as a container and the packaging of foods and other products. This group also concentrates on the study of the bacteriological aspects of processing and packaging. The handling of glass containers in customers' plants, and the closing and processing of glass containers, also are studied.

(*Continued on page* 338)

1 Effect of Storage Conditions on Weathering of Commercial Glass Containers, Jl. Am. Cer. Soc. 25:359 (1942).
Variable Factors in Accelerated Autoclave Chemical Durability Tests, Jl. Am. Cer. Soc. 25:143 (1941).

High-temperature concentric cylinder viscometer and control panel.

Low-temperature viscometer showing automatic temperature control apparatus beneath table.



SURFACE DEALKALIZATION OF FINISHED GLASSWARE

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PART II

Methods Used for Determining the Reactivity and Alkalinity of the Glass Surface

The surface of glass can be changed by its exposure to gaseous, liquid, or solid reagents which either enter a base exchange reaction or remove alkali. Even mere heat treatment might affect the alkalinity by migration of Na_2O to the surface, by removal of Na_2O due to volatilization, by influencing the bond strength between the alkali ions and the network of the glass or by bringing the surface layer into a state of compression.

The treatment of the glass surface with solid reagents such as metakaolin is of particular interest insofar as it allows us to change only a well defined area of the surface and leave the rest more or less unaffected. Besides the conventional methods for determining the chemical resistivity of glass, other reactions could be used which would differentiate between the original and the altered glass surface. Comparative tests became more interesting than absolute determinations. In the following pages we shall describe a few typical methods which we used, some of which were developed for this particular purpose. They were supposed to indicate the following changes:

(a) Relative concentration of Na^+ in the reacted and unreacted area.

(b) Replacement of Na^+ by H^+.

A. *Tests for Alkali in the Reagent*

(1) The Chromate Reaction: In order to find out whether or not a reagent had removed alkali from the glass surface one could test the alkalinity of the glass or look for the whereabouts of the alkali. The latter was particularly easy in the case where chromium oxide was used for treating the glass surface, because sodium chromite formed, oxidized in air to sodium chromate. The reaction

$$Cr_2O_3 + \frac{3}{2}O_2 \rightarrow 2\,CrO_3$$

does not take place in the absence of basic oxides. Their presence leads to the formation of hexavalent chromium according to

$$2Na_2O + Cr_2O_3 + \frac{3}{2}O_2 \rightarrow 2Na_2CrO_4$$

The chromate anion CrO_4^{2-} can be easily detected and quantitatively determined. We carried out the experiments by using an intimate mixture of chromium oxide and a soda lime glass which had been powdered, screened and washed with alcohol in order to remove the dust. This mixture was heated in a platinum crucible and the chromate determined quantitatively after its extraction with water by titration with standard thiosulfate solution.

(2) The Nickel Dimethylglyoxime Test: The previous reaction is limited to chromium oxide as a means for dealkalization. It has been used with glass powder because of the larger surface available for reaction and because pure chromium oxide does not stick sufficiently to a polished glass surface. For the kaolin or metakaolin reaction we took advantage of a sensitive spot test which had been developed by F. Feigl[26].

Feigl's reaction is based on the fact that nickel ions and dimethylglyoxime react quantitatively in ammoniacal solution to form a bright red insoluble complex; but in the absence of ammonia an equilibrium is established which can be expressed by:

$$Ni^{++} + 2\,DH \leftrightarrows NiD_2 + 2\,H^+$$

where D stands for the anion of the dimethylglyoxime. In neutral solutions an equilibrium is established which is very sensitive to the removal of hydrogen ions. By adding OH^- or withdrawing H^+ from the solution, the equilibrium is disturbed and additional NiD_2 is precipitated.

The reagent is prepared in the following manner. Crystalline nickel sulfate, $NiSO_4 \cdot 7H_2O$ (2.3g) is dissolved in 300 ml. of water. To this solution one adds 2.8 g. of dimethylglyoxime dissolved in 300 ml. of alcohol. The mixture is allowed to stand for thirty minutes and then the red precipitate is removed by filtration. The solution can be stored in a glass bottle but the small amounts of alkali given off from the glass will gradually cause the precipitation of additional NiD_2. The reagent, therefore, should be filtered before use.

In making the test, the metakaolin coating when still in contact with the glass is wetted with the solution. If alkali has migrated from the glass surface into the metakaolin, a red color develops within three minutes. This is an indication that the Na_2O had combined with the metakaolin to a hydrolyzable substance probably the compound $Na_2O \cdot 2Al_2O_3 \cdot 4SiO_2$. It goes without saying that the pure electrodialyzed clay and the metakaolin prepared from it do not give a positive test. Only the raw clay which contains Ca^{++} or Na^+ adsorbed gives a test, so that the reagent can also be used to determine the point where purification of the clay by electrodialysis is completed.

B. *Tests Based on the Chemical Reactivity of the Glass Surface*

(1) The Acid Resistivity Test: E. Berger's[27] acid resistivity test is by far the most convenient method for determining the relative chemical resistivity of a plane polished glass surface. The method is based on the fact that the exposure of such a glass surface to the influence of a diluted acid leads to the formation of a film of lower refractive index than that of the glass. The thick-

ness of the film increases with time and as its depth changes it gives rise to Newton colors due to the interference of light waves reflected at the acid-film and the film-glass interfaces. By standardizing the concentration of the acid, the temperature, the angle of observation and the interference color, the time elapsed to produce the film provides an easy means to judge the acid resistivity. For obtaining absolute values one would have to know the exact index of refraction of the film which depends not only on the SiO_2:H_2O ratio but also on the adsorption of ions from the solution on the inner surface of the silica gel. Four our purpose the absolute values are immaterial as we compare only the resistivity of the untreated and treated surfaces of the same glass.

Experiments with microscope slides, which represent a soda lime glass of excellent chemical resistivity, brought out that the kaolin treatment at low temperature (150-200°C.) had sped up the film formation. In our previous discussion we assumed that all reactions removing Na^+ below 400°C. represent base exchange reactions, leading to a hydrogen glass. From this point of view the low temperature kaolin treatment is identical in its effect with the acid resistivity test and consequently glasses thus treated showed film formation after a shorter time than the untreated glass. After dealkalizing the surface at 500-550°C., however, the glass had become so resistant to acids that no film formation could be observed in the severe test (HCl 6 *N*, Temp. 90°C.) after five days. The formation of the purple interference color was used as the end point.

As the microscope slides themselves represented glasses of high acid resistivity a number of variations were made from a crown glass which led to glasses of decreased chemical resistivity. Samples of these glasses, with and without metakaolin treatment, were subjected to the test and some of the results are summarized in the Table V.

TABLE V

Change Made in the Composition of the Crown	Time for Film Formation of Untreated Glass	Metakaolin Treatment Time hrs.	Metakaolin Treatment Temp. °C.	Time for Film Formation of Treated Glass
Original crown	25 hrs.	24	500	negative after 5 days
Na_2O replaced by K_2O	3 hrs.	24	500	negative after 5 days
Na_2O replaced by K_2O	3 hrs.	½	500	negative after 5 days
Na_2O replaced by K_2O	3 hrs.	½	400	positive after 5 days
2 mol % SiO_2 replaced by Na_2O	6 hrs.	24	500	negative after 5 days
4 mol % SiO_2 replaced by Na_2O	3 hrs.	24	500	negative after 5 days
6 mol % SiO_2 replaced by Na_2O	1 hr.	24	500	negative after 5 days
6 mol % SiO_2 replaced by Na_2O	1 hr.	½	500	negative after 5 days
6 mol % SiO_2 replaced by Na_2O	1 hr.	½	400	negative after 5 days
20 mol % SiO_2 replaced by 10% $NaBO_2$	5 minutes	8	500	negative after 5 days
10 mol % SiO_2 replaced by 5% B_2O_3 and 7.5% Na_2O replaced by K_2O	35 minutes	8	500	negative after 5 days
4 mol % SiO_2 replaced by 4% CaO	filmed immediately	8	500	positive after 22½hours

We see from these results that all variations of the crown glass which led to poorer chemical resistivity can be easily improved by the metakaolin treatment. This is especially true for those glasses where the poor chemical resistivity is the result of overloading the glass with alkali. Glasses whose content of divalent ions, such as Ba^{++}, Ca^{++}, or Pb^{++} is too high cannot be expected to respond to the metakaolin treatment to the same extent.

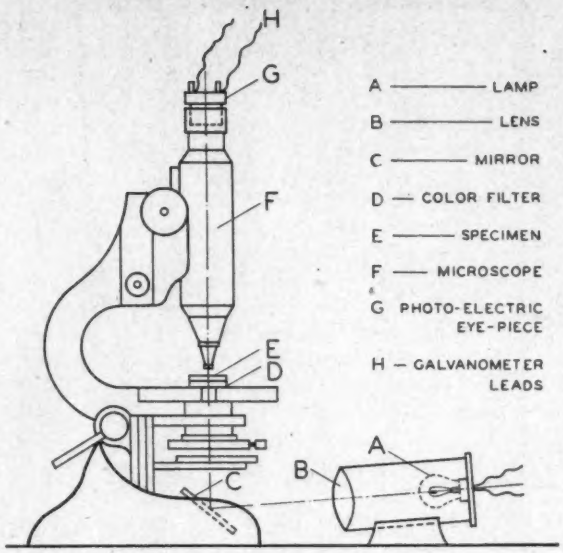

Fig. 4. Arrangement of apparatus for color determination.

(2) The Cuprous Chloride Test: The reaction between cuprous chloride vapor and glass as described in the previous paper proved to be a valuable tool for comparing the reactivities or alkalinities of the treated and untreated areas of a glass surface. In contact with cuprous ions, glasses containing alkali ions enter a base exchange reaction. This is the basis of the well known copper staining. Commercial copper staining is carried out by applying a slip containing the copper ions with a carrier substance such as ochre. The role of the latter is to distribute the copper ions and to consume the alkali ions which are forced out of the glass as a result of the base exchange reaction.

For our purpose, namely to distinguish the dealkalized area from the unaltered glass surface, the use of ochre had to be avoided because it would, by itself, be capable of dealkalizing the glass surface and thus decrease the contrast. For this reason a new method, using cuprous chloride vapor, was developed. The sample was exposed to the vapors of cuprous chloride at 500° C. for eight hours. The reaction was carried out in a glass casserole which was inserted in an electric muffle furnace. After cooling, the casserole was taken out of the muffle and the samples were inspected for "bloom". A strong white deposit, sodium chloride, indicates a high concentration of Na^+ in the surface area treated. The bloom is the result of the base exchange reaction:

$$Na^+\ Glass^- + Cu^+\ Cl^- \rightarrow Cu^+\ Glass^- + Na^+Cl^-$$

which leads to the formation of crystalline sodium chloride which has a much lower vapor pressure than the cuprous chloride. It therefore deposits at the place where it forms.

Little or no bloom is not necessarily an indication that the cuprous chloride has not reacted at this spot, but is indicative of the lack of sodium chloride formation only.

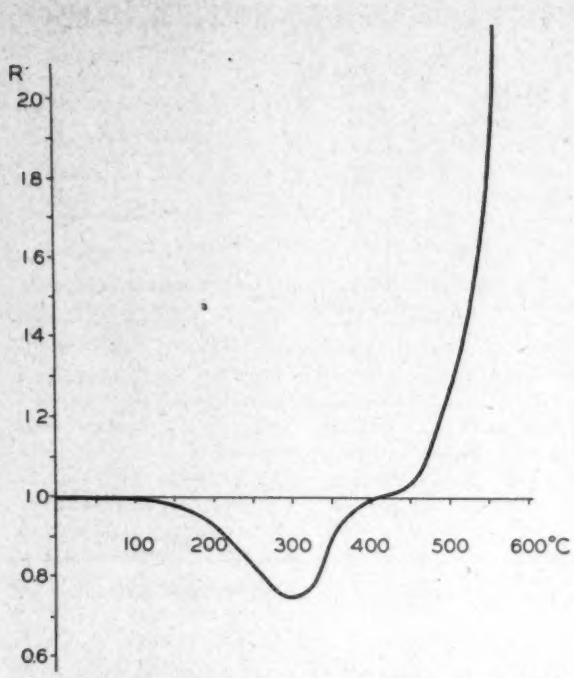

Fig. 5. Results of CuCl test for glasses treated with metakaolin at different temperatures.

Whether or not the glass has reacted with cuprous chloride is brought out only by inspection under ultra violet light where the cuprous glass produces a greenish fluorescence or by a subsequent reduction process which produces a red color. Only if the area under examination remains colorless can we be sure that no reaction has taken place. If, however, the red copper stain develops upon reduction despite the absence of bloom, we know that the following reaction must have taken place:

$$H^+ Glass^- + Cu^+Cl^- \rightarrow Cu^+ Glass^- + H^+Cl^-$$

The reduction of the glass sample was carried out by exposing it to hydrogen for thirty minutes at 400° C.

The results of the cuprous chloride treatment are to be interpreted as follows:

(a) Strong bloom and deep red after reduction: Glass surface with high Na_2O content.

(b) Faint bloom and light red after reduction: Glass with low Na_2O content.

(c) No bloom and colorless after reduction: Glass with no Na_2O content.

(d) No bloom but red color after reduction: Glass in which Na^+ has been replaced by H^+.

This reaction has been developed further to serve as a semiquantitative method for determining the alkalinity of the glass surface. For this purpose the CuCl exposure and the reduction process were standardized and the intensity of the resulting color was measured by means of a microscope and an ocular photoelectric cell. In order to increase the contrast, a green filter was used. The apparatus is sketched in Figure 4.

As we will see from some of the results this method proved to be a great help in our studies. We have only to keep in mind that it is not more than a semiquantitative method. The intensity of the color obtained is not only a function of the amount of Cu^+ which has entered the glass, which in turn would be an exact measure of the amount of Na^+ and H^+ replaced, but depends to a great extent upon the particle size of the copper crystals which form during the reduction process.

To illustrate the usefulness of this method, the following series of experiments shall be discussed:

A circular spot of kaolin 20 mm. in diameter was applied to a number of soda lime glasses (microscope slides). The kaolin was allowed to react for eight hours at temperatures ranging between 250° and 600°C. The effect of this treatment was then made visible by developing treated and untreated areas by means of the cuprous chloride test with subsequent reduction.

By means of green light and a photoelectric cell, the contrast in color between treated and untreated glass surfaces was measured. No effort was made to determine the absolute light transmission because for our interpretation only the ratio (R) of the color intensities of treated and untreated parts was needed. Some of these values are given in Table VI and plotted as a function of temperature in Figure 5.

TABLE VI

Temperature Kaolin treatment	Transmission for green light		R
	Unreacted Area	Reacted Area	
250°C.	32.0 Galv. Units	26.2 Galv. Units	0.817
300	22.6	17.1	0.754
350	14.6	13.3	0.912
400	15.8	15.0	0.950
450	15.4	15.1	0.984
500	21.5	27.5	1.28
550	20.7	40.0	1.94

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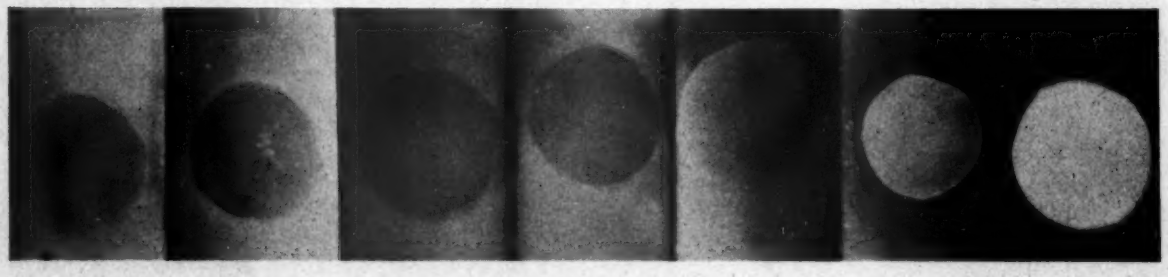
EFFECT OF METAKAOLIN TREATMENT ON THE COPPERSTAIN



Temperature of Treatment

Fig. 6 250 300 350 400 450 500 550

THE FINISH GAUGE—LATEST CONTRIBUTION TO GLASS CONTAINER QUALITY CONTROL

Another decided advance has been made in the interests of quality production of glass containers through the development by the Hartford-Empire Company of a new finish diameter indicating comparator. This new device, intended for measuring the sealing surface diameters of glass containers designed for vacuum sealing, will not only assure the packer of a more efficient container but should help reduce the glass manufacturers production costs through the elimination of faulty ware before it is lehred and reaches the packing table.

This latest Hartford instrument is primarily a production control device. It is a practical workman's tool for every day twenty-four-hour use in the checking of mould adjustments and performance at the forming machine. It can be used by the operator in the same practical manner as he uses plus and minus scales for the checking of weights. Primarily it is a hot end utility but it can also serve as an occasional spot inspection gauge in established inspection departments of container plants.

In offering this new device to the glass container industry the Hartford company believes that it will enable container manufacturers to prepare for eventual automatic gauging which is being demanded and for which equipment is in the process of being perfected. In the meantime, however, and even after the eventuality of automatic gauging the model offered can determine adjustments which are essential in the prevention of off-gauge ware having such defects as offsets, excessive out-of-roundness, indentations, bulges, flats, and oversize or undersize diameters. Faults such as these are readily detected with the new gauge when used on set-out containers. Causes of defects can be promptly traced and eliminated before annealing, and when perfected, before automatic gauging.

Gauges for several types of glass finishes and a range of 16 sizes will eventually be made available for use on food containers.

Figure 1 shows Type 1710, size 58, placed in gauging position on a jar for baby food. The one piece cast aluminum housing thoroughly protects the indicator and hardened working parts.

Figure 2 illustrates the underside of the gauge—that area which comes in direct contact with the glass container's finish. Also illustrated is a Master Gauge (A) which is provided with each working gauge for the purpose of period checking of the working gauge.

In construction, the H-E Finish Gauge incorporates two hardened ball point contacts which are set to measure the practical vertical center of the gasket sealing surface of a glass container. Indicator measurements are between points B. Side points C serve as centering guides and also as a fixed maximum diameter gauge. Any container that cannot be rotated between side points C is not usable. The indicator will show how much oversize it may be up to plus twenty thousands.

Figure 3 shows a cross-sectional view of the gauge in place on a container, together with descriptive information on various parts identified.

With regard to standardization practices up to the present time, tolerances have been provided only for maximum and minimum diameters for a given size of finish. For example, for the 1710-48 baby food jar, tolerances are established at 1.890 maximum and 1.860 minimum inches. To meet these requirements empirical methods have been employed. These practices have necessitated the making of new mould equipment by cut and try procedure in order to produce glass containers within the specified tolerances.

The new H-E Finish Gauge promptly and accurately detects any tendency to exceed such tolerances before such excessive violation is extended over a protracted period during which the lehr may become filled with faulty ware.

In actual glass plant use since the Finish Gauge is a hot end utility the procedure for its primary use may be stated as follows. Hot containers, directly from the forming machines are set out, care being taken not to pinch them in the operation. They naturally must be allowed to cool as is the usual practice for hot end inspection. As soon as they are cool enough for handling,

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Fig. 1.

HOW THE GLASS INDUSTRY CAN CONTRIBUTE TO FULL PEACETIME EMPLOYMENT

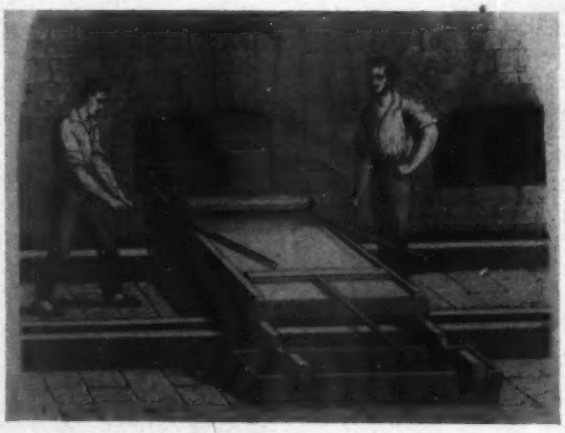
National prosperity with high level of employment at proper wages dependent upon revision of stifling tax laws.

By CLINTON DAVIDSON
President, Management Planning, Inc.

On the eve of scientific and technological developments potentially greater than ever before, American industry is menaced by the alarming possibility that there may be little, if any, risk capital available for new enterprise during the postwar period.

To the glass industry, now geared to crash or create new markets, as well as to meet new competition in old markets—with new miracles in glass as wonderful to modern man as glass itself must have been to ancient man—such a condition must seem intolerable.

Yet this condition probably will exist if wartime tax rates on corporations are permitted to remain after the end of the war. And wartime tax rates are almost certain to remain in force unless Congress, taking action before the end of the war, makes provision for their repeal or revision.



Casting mirror glass in 1860.

Failure on the part of Congress thus to clear the way for new enterprise when government military orders for goods and services are cancelled would probably wreck the peacetime potentialities of industry. And the political and sociological consequences of unemployment and depression might well wreck the peace itself. If the most highly regarded polls of public opinion are sound guides, then there is reason to believe that the action of Congress will depend largely upon the wishes of an informed electorate. And the public may be expected to be rather lethargic until each individual sees the matter in the light of his own self-interest.

Here then is the sort of information needed by a good citizen who earns his living in corporate industry, specifically in the glass industry:

Glass was made in Jamestown and exported to England in 1608, one year after the founding of the Colony. For the next two hundred years the history of glass-making in America was a history of failure, in spite of the high cost of imports.

Although literature is rich in histories of glass-making, it is probable that archeologists know more about prehistoric man than historians can find out about the individual glass workers in early America. Certainly we know more about the glass that was made than about the people who made it. But the mosaic of fragments of written history clearly indicates that glass manufactures were numerous, that the product was generally poor, that production was inefficient, that prices were high, that profits were vanishing, and that wages approximated the subsistence level.

For instance, it is recorded that in 1803 Major Isaac Craig, co-founder of a window glass factory at Pittsburgh, wrote that a box of 100-foot window glass sold at $13.50 for 8 x 10 and at $15.00 for 10 x 12.

A payroll receipt book of the Boston Glass House (one of the first glass-making enterprises for which there is a reliable record) shows that in 1794 the aggregate week's wages of a foreman and eight assistants (ten workers) were $58.50.

The Report on Manufactures by the Secretary of the Treasury in 1833 shows that the glass works at East Cambridge paid men an average of $1.30 a day (this was probably for a twelve-hour day).

How much was $1.30 a day in real wages in 1833 in East Cambridge There is no exact information. But the various data presented in the classic study by Norman Joseph Ware, entitled "The Industrial Worker, 1840-1860," suggest that the minimum cost of living for a family of five at subsistence level was about ten dollars a week.

The first revolutionary change from handicraft in the glass industry was the introduction of the Siemens regenerative furnace, invented in 1861 and gradually adopted. Meanwhile the continuous melting tank, invented in 1872, was introduced during or after 1888. This facilitated continuous work by day and night shifts. Blowers were no longer obliged to use the long irons formerly required for gathering glass when pot furnaces were exclusively in vogue, but could now, with far less labor, skim the glass from the surface of the tanks, using gathering irons made shorter and capable of being handled with greater rapidity. The average production per blower is estimated to have increased twenty-five per cent.

Another change was from the "single blower method of doing work," which prevailed previous to 1870, to what was known as the "shop system." Instead of working singly, three men worked together, two of them gathering glass and blowing the ware, while the third made

Index numbers of labor productivity and labor cost in the glass industry, by article and process

Article	Labor productivity			Labor cost		
	Hand process	Machine	Per cent of increase	Hand process	Machine	Per cent of decrease
Bottles:						
2-ounce prescription ovals	100.0	3906.4	3806.4	100.0	2.74	97.26
4-ounce prescription ovals	100.0	4109.8	4009.8	100.0	2.70	97.30
2-ounce extract panels	100.0	2511.6	2411.6	100.0	4.20	95.80
½-pint sodas	100.0	1642.0	1542.0	100.0	6.70	93.30
1-pint whisky dandies	100.0	742.1	642.1	100.0	10.30	89.70
1-quart milk bottles	100.0	1449.3	1349.3	100.0	5.10	94.90
5-gallon water carboys	100.0	994.0	894.0	100.0	17.10	82.90
Pressed ware:						
8-9-ounce table tumblers	100.0	1228.1	1128.1	100.0	6.70	93.30
10-ounce table tumblers	100.0	1240.0	1140.0	100.0	6.65	93.35
4½-5-inch nappies	100.0	759.6	659.6	100.0	8.62	91.38
6-7-inch nappies	100.0	491.0	391.0	100.0	13.26	86.74
3½-ounce sherbets	100.0	817.0	717.0	100.0	8.97	91.03
4½-5-ounce sherbets	100.0	630.5	530.5	100.0	12.62	87.38
Blown ware:						
Lamp chimneys	100.0	142.3	42.3	100.0	62.50	37.50
25-watt electric bulbs	100.0	3126.2	3026.2	100.0	3.39	96.61
40-watt electric bulbs	100.0	3142.6	3042.6	100.0	3.39	96.61
9-10-ounce punch tumblers	100.0	1419.1	1319.1	100.0	7.00	93.00
Glass tubing, sizes 19-21	100.0	591.9	491.9	100.0	18.55	81.45
Glass tubing, sizes 32-34	100.0	746.7	646.7	100.0	14.70	85.30
Window glass:						
Single strength	100.0	261.1	161.1	100.0	31.30	68.70
Double strength	100.0	228.4	128.4	100.0	32.80	67.20
Plate glass:						
Rough plate	100.0	145.0	45.0	100.0	74.90	25.10
Polished plate	100.0	160.5	60.5	100.0	66.70	33.30

the neck smooth, and otherwise finished the bottles produced by the other two. The average production of bottles for each of three men working together in this way was from 275 to 300 dozens per day, considerably more than he could have made alone.

Suddenly the glass industry caught up with the Industrial Revolution. During the first quarter of this century, the application of automatic machinery sent production figures soaring. Man-hour output of oval prescription bottles went up 3,000 and 4,000 per cent, in certain sizes. Pressed ware tumblers rose 1,200 per cent. The man-hour output of electric light bulbs increased 30 times. Window glass and plate glass shared in the advance, while even the lowly lamp chimney showed a man-hour output increase of 42.3 per cent.

While labor productivity multiplied, due to the use of machinery, labor cost went down. Figures showing the full extent of the change were collected in 1927 by the Department of Labor, which summarized them as shown in table at top of page.

In the same publication the Department of Labor showed that from 1899 to 1925 mechanization had increased the average wage of workers in the glass industry from $512.78 to $1,250.32, an increase of nearly 250 per cent—and this does not take into account reduction in hours of labor, the mitigation of laborious tasks, or the tremendous improvement in working conditions.

Meanwhile, as shown in table at top of page 330, the value of output for the four principal branches of the glass industry (constituting 90 per cent in 1925) had increased from $56,540,000 in 1899 to $295,959,000 in 1925, while total production per establishment rose from about $160,000 to about $950,000.

The rise in wage rates which accompanies increased man-hour output in the glass industries had its parallel in industry as a whole. The following tabulation gives these data for all industry, plus other available data on horsepower per worker, investment per worker and investment per plant. Reading from right to left, these

A modern plate glass machine. Pittsburgh Plate Glass Company.

Statistics of the glass industry, 1899 to 1925, by specified years

[Data from United States Bureau of the Census]

Item	1899	1904	1909	1914	1919	1921	1923	1925
Establishments	355	399	363	348	371	329	333	310
Bottles and jars	147	158	166	150	145	(1)	117	120
Pressed and blown ware	84	103	114	107	130	(1)	127	123
Window glass	100	103	(1)	64	79	(1)	65	42
Plate glass	16	17	(1)	19	17	(1)	17	19
Wage earners	52,818	63,969	68,911	74,502	77,520	54,748	73,335	69,371
Bottles and jars	28,370	(1)	(1)	(1)	(1)	(1)	24,010	21,704
Pressed and blown ware	12,546	(1)	(1)	(1)	(1)	(1)	27,196	21,507
Window glass	8,682	(1)	(1)	(1)	(1)	(1)	8,826	8,346
Plate glass	3,220	(1)	(1)	(1)	(1)	(1)	9,961	11,124
Output:								
Bottles and jars ..... thousand gross..	7,780	12,005	12,316	19,290	22,295	(1)	28,393	26,044
Pressed and blown ware ..... million pieces..	360	428	532	701	1,080	(1)	(1)	1,963
Window glass ..... thousand boxes..	4,341	4,852	6,922	8,020	7,380	5,201	10,204	11,343
Plate glass.....thousand sq. ft...	16,884	27,293	47,370	60,384	56,823	56,239	94,470	117,369
Value of output (000 omitted)	$56,540	$79,608	$92,095	$123,085	$261,884	$213,471	$309,353	$295,959
Bottles and jars	21,677	33,631	36,018	51,959	94,670	(1)	107,231	100,301
Pressed and blown ware	17,076	21,956	27,398	30,279	70,749	(1)	77,279	72,085
Window glass	10,879	11,611	11,743	17,495	41,101	24,026	42,623	37,525
Plate glass	5,159	7,978	12,205	14,774	33,348	37,261	66,103	57,207
Wages (000 omitted)	27,084	37,288	39,300	48,656	87,527	68,224	89,898	86,736

(1) Not reported.

columns reveal with amazing clarity the economic factors in operation:

Year	Investment per Plant	Investment per Worker	Horsepower per Worker	Year's Output* per Worker	Annual Wages per Worker
1849	$ 4,000	$ 500	(nominal)	485	$ 248
1879	10,000	1,000	1.3	723	346
1909	70,000	3,000	2.9	1,300	310
1939	270,000	6,000	6.4	3,100	1,150

*Output means value added by manufacture.

From the foregoing it is evident that the worker earns more—and enjoys better, healthier working conditions—because he produces more. His increased production foots the bill for shorter hours, sanitation, better maintenance, safety and health services and other advantages that today's glass worker enjoys—and this is true of industry in general. The worker produces more, largely because of the application of horsepower. Increased horsepower has been made possible by increased investment per worker.

And what has made possible the procurement and employment of increased capital investment? The answer is: the Corporation.

Far more important than any single scientific discovery or invention, the Corporation is the one indispensable tool of the Industrial Age. By coordinating men, materials, machines, methods and money under management, the corporation provides the means and the medium for the efficient use of capital. It facilitates the large-scale application of horsepower to the efforts of workers, and thereby increases their output. By increasing output of workers, it enables them to earn more than would otherwise be possible.

It follows, therefore, that the maintenance of postwar wage levels and employment requires these two things:

1. More capital to build up small successful corporations into large corporations so that they can provide workers with services available only through large organizations.

2. Risk capital to launch new inventions and ideas.

Will this risk capital be provided after the war? Not at present tax rates. Not with an excess profits tax of 95 per cent—let alone the regular corporation income tax of 40 per cent and personal surtax rates at the currently abnormally high figures.

Various branches of the government, both Houses of Congress, and practically all business organizations have been talking about reconverting. They are all making plans to reconvert business after the war. I should like to say here that we cannot have high level employment after the war unless we reconvert our wartime taxes. Today's double taxes on corporate earnings were planned to "take the profits out of war." If these taxes are allowed to stay unchanged—if they are not reconverted—they will *take the prosperity out of peace.*

An impressive array of key organizations and key people with no self-interest in corporation finance has recognized the seriousness of the impending situation and has issued formal statements recommending the liberation of corporations from excessive taxation coincidentally with the end of the war. Among them are:

James F. Byrnes, recent Director of War Mobilization and Reconversion; The House Post-War Planning Committee; The Committee for Economic Development; The Ruml-Sonne Report to the National Planning Association; The National Grange, at its November, 1944, convention; The American Farm Bureau, at its December, 1944, convention; H. E. Babcock, Chairman of the Board of Trustees of Cornell University and formerly president of the largest farmer cooperative in the U. S.; Leon Henderson; Prof. Irving Fisher; and Twin Cities Group.

Postwar tax plans which will leave industry free to reconvert have been published by the Research Committee of the Committee for Economic Development and the Business Committee of the National Planning Association and other public-spirited organizations. It does

(*Continued on page* 350)

THE ICC RULING

Commission rules that regional class freight rate disparity and territorial difference in classification ratings are unreasonable. Provisions of order indicate glass container industry will not be affected too seriously at least for time being.

Current opinion reflects considerable surprise in the most recent findings of the Interstate Commerce Commission which were handed down on May 15th. This long awaited order growing out of an investigation it initiated on its own motion in 1939, relates to the question of whether or not there should be a uniform freight rating classification and a single scale of class freight rates for application throughout the country.

The order, which is in three parts, may turn out to be one of the most far reaching freight rate decisions the Commission has ever caused to be entered.

At present there are four separate freight classification territories; the Official, or Eastern territory, and the Illinois, Southern and Western territories, in which there are differences in ratings and carload minimum weights on identical commodity descriptions and different percentage relationships of lower classes to first class rates.

Part I of the order finds these differences improper and directs that description of articles, carload minimum weights and classification ratings be made uniform for application nationwide. It requires the rail carriers to say within ninety days whether or not they will undertake to make and tender a uniform classification of 30 classes, the inference being left that if they do not consent to do so, the Commission will make up one of its own. Since uniformity, as it is ordered, does not necessarily mean adjusting ratings to the lowest currently in effect in any classification territory, it is expected the carriers will agree to make such a tender. However, experienced traffic men say it will take two years or more to prepare a classification which is completely uniform.

The National *class* freight rate structure as it now exists, reflecting scales of rates previously prescribed by the Commission, is divided into five major territories, Eastern, Southern, Western Trunk Line, Southwestern and Mountain Pacific, each with a subdivision of one or more zones. The lowest of these scales is in the Eastern territory where the traffic density is highest.

Part II of the order condemns each of these previously prescribed scales, both for intra-territorial and inter-territorial application and fixes for eventual application in lieu thereof, a single scale of maximum first class rates constructed on distance to be made effective within and between all sections of the country east of the Rocky Mountains. This scale establishes a first class rate of 40 cents per hundred pounds for a distance up to five miles, and is progressively increased until a rate of $3.75 for the same volume is reached, for a distance of 2,500 miles. It also fixes a uniform percentage relationship of all lower classes to the first class rates. Since Part II of the order ties into the findings of Part I and it is not known when a uniform freight classification can be published, no time is set in Part II for publication of the permanent single scale of first class rates.

Until such time as the class rate structure in compliance with Part II of the order can be effected a provision is made for an interim adjustment in the regional class rate scales now in effect.

Part III of the order requires publication to be effective not later than August 30, 1945, of a new scale of class rates for application within Official territory which are 10 per cent higher than the scale presently in effect. In all other territories east of the Rocky Mountains, both intra-territorial and inter-territorial, class rate scales are concurrently ordered reduced by 10 per cent.

In each of the existing classification territories there are published many hundreds of what is known as exceptions to classification ratings. These are ratings that are generally lower than straight classification ratings. In Official territory freight charges on glass containers are computed on classification exceptions ratings. Hence of primary interest to the glass container industry is that part of the order which clearly provides that exceptions rates are not to be disturbed. Since Official territory is the only one which will be subjected to an increase in rates, pending establishment of a permanent scale of class rates, the glass container industry will not for the time being be too seriously affected. Whether or not the order in its entirety will become effective without substantial amendements or modifications is as yet uncertain. It is being studied by both carrier and shipper groups and it is altogether likely that the Commission will hear a good deal about it before tariffs are actually effective.

INSTITUTE ELECTS TRUSTEES AND OFFICERS GLASS CONTAINER MANUFACTURERS

At the first membership meeting of the newly formed Glass Container Manufacturers Institute held June 5 at the Hotel Biltmore in New York, the following trustees were elected: G F. Lang, Carr-Lowrey Glass Company; F. H. May, Foster-Forbes Glass Company; J. H. Rau, Fairmount Glass Works; L. F. Gayner, Gayner Glass Works; W. B. Marble, Latchford-Marble Glass Company; I. R. Macdonald, Dominion Glass Company; R. R. Underwood, Knox Glass Associates, Inc.; E. J. Costa, Crown Cork & Seal Company; C. D. King, Anchor Hocking Glass Corporation; H. F. Merritt, Solvay Process Company; and R. L. Warren, Brockway Glass Company, Inc.

On the following day, the trustees held their first meeting for the purpose of electing officers. The roster of officers of the Institute includes: George F. Lang, President; F. H. May, 1st Vice President; I. R. Macdonald, 2nd Vice President; V. L. Hall, General Manager; H. W. Kuni, Secretary and Treasurer; and Fred E. Fuller, Counsel.

• In tribute to his leadership in advancing industrial science, Clyde Williams, Director of Battelle Memorial Institute, Columbus, Ohio, was presented the degree of Doctor of Science at recent convocation ceremonies of the Case School of Applied Science, Cleveland, Ohio.

INVENTIONS AND INVENTORS

A Summary of Patents of Interest to the Glass Industry Issued During May

Furnaces

Howard L. Halbach of Clarksburg, W. Va., received patent 2,377,080, for a wall construction for tank furnaces in which there is positive means for moving the tuckstones inward or outward so as to improve the nature of the seal or closure between the flux blocks and the upper sidewall. The patent is assigned to Pittsburgh Plate Glass Co.

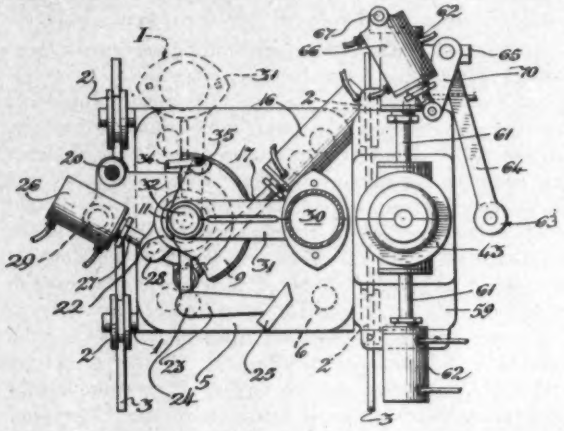


Fig. 1. McNish : 2,376,928. Single-mold bottle machine of suction gathering type.

Feeding, Forming and Shaping

Fig. 1 shows a plan view of a single-unit container machine of the suction gathering type described in patent 2,376,928, granted to Alexander F. McNish of Scone, Scotland. It uses only a single set of molds as distinguished from multiple mold machines. The parison mold moves only ninety degrees. The gathering station is shown at I in dashed lines, while ninety degrees to the right the parison mold 30 is at the point where the blank will be discharged to the finishing mold 43. Compressed air cylinders cause the mold to dip into the forehearth and then to be lifted for motion to the discharge position, where the blank is retained within the mold long enough to allow it to be transferred.

Patent 2,376,602, granted to Clarence C. Kinker of Montreal, Canada (O'Neill Patents Ltd.), concerns a forming machine having two rotary tables, side by side, travelling in stepwise motion, one bearing the blank molds and the other the finishing molds. The blank mold has its bottom end up at the time of charging. In successive stages the charge is compacted in the neck ring around the mouth forming pin, first by vacuum and then by compressed air from above. At this point the upper end of the mold has been closed by a baffle of unique design featured in the patent. The blank is given an initial blow, and by the time it reaches the transfer station it has been swung to the normal upright position. Just before the two tables stop at the transfer point, and while they are moving slowly, the blank is transferred to the blow mold which is then in opened position. This is accomplished by opening the parison mold by cam means so that the blank is left suspended by the neck ring; the blow mold closes around it just as the transfer is completed. The transfer is all effected while the machine is in motion.

An indexing machine of the type used in the manufacture of incandescent lamps such as for sealing together certain of the lamp parts, is disclosed in patent 2,376,540, assigned to General Electric Co. by Fred B. Iden of Cleveland Heights, Ohio.

Miscellaneous Processes

In a method of tempering tumblers, Alberto Quentin of Milan, Italy, rotates them in the heating chamber and then tempers them by air blast from jets of the type illustrated in Fig. 2. A distinguishing feature is the rotation of the jet assembly with apertures both within and outside the tumbler, while the tumbler itself may also rotate. This is patent 2,375,944, vested in the Alien Property Custodian.

Another tempering process is described in 2,376,872, assigned to Holophane Co. Inc. by Samuel J. Harris of Newark, Ohio. This is a process of tempering articles of such form that one side would naturally tend to cool faster than the other. Harris uses various means of proportioning the cooling medium so that less cooling is exerted against the side which has the greater rate of heat abstraction.

As a contribution to the art of reducing light reflection from a glass surface by using a transparent film having thickness equal to a quarter the wave length of light, Clarence W. Hansell of Rocky Point, New York, proposes multiple coatings. He reports that to accomplish the correction with two or more films instead of one gives a very considerable improvement in color characteristics.

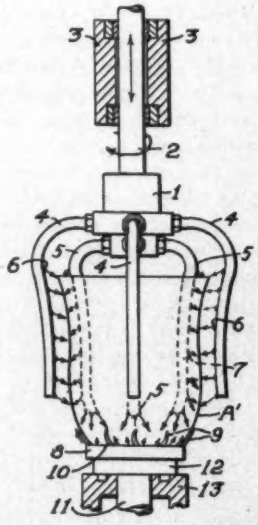


Fig. 2. Quentin : 2,375,944. Blowing heads which give rotation with respect to the tumbler in a tempering process.

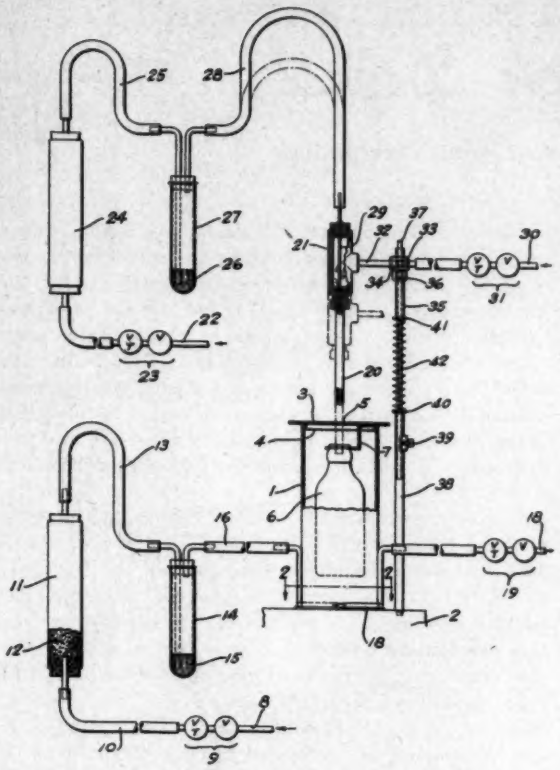


Fig. 3. Lyle : 2,375,482. Iridescent coating applied to bottle surfaces by drawing a fixed volume of dry air through stannic chloride to provide a vapor for contact with the hot glass.

This is patent 2,376,428, assigned to R.C.A. According to the simplest form of the invention, if light waves are to be passed with little reflection for any color, through the boundary between glass and air, there should be interposed at the boundary two films each about a quarter wave length thick for the mean light frequency or color.

Fig. 3 shows Aaron K. Lyle's apparatus of patent 2,375,482 (Hartford-Empire Co.) for applying an iridescent coating to a glass article. The bottle, preferably still hot as a result of forming, is enclosed in a chamber to which a vapor of stannic chloride or titanium chloride is supplied. The two complete reagent trains pictured here are for treating the outside and also, if desired, the inside of the bottle. Taking the lower train, for example, compressed air is valved into the line at 9 in a fixed charge, and it is dried by passing through calcium chloride 12, before passing through the stannic chloride 15. The variables controlling the treatment are discussed.

A problem encountered in the manufacture of foam-glass is discussed in patent 2,377,076 by Walter D. Ford of Port Allegany, Pa. (Pittsburgh Corning Corp.). In one of the more satisfactory methods of making this product, ground glass is mixed with one or two per cent of calcium carbonate or other gas generating agent, and a batch is placed between a pair of alloy steel pans shaped like pie pans. If just the right charge is used the result of the heat treatment will be to just fill the space between the pans. It is necessary that the pan surfaces be coated with a parting material so that the foam glass can readily be freed from the pans. Ford has discovered that bauxite forms the base for a suitable material. He believes that the fact that it has chemically combined water whose escape, on heating, may maintain a parting layer, has a bearing on its successful use.

A lehr loader is described in patent 2,375,936, assigned to Anchor Hocking Glass Corp. by Wm. L. McNamara and Frederick Z. Fouse.

A cement building block with glass facing and with metal molding is the subject matter of patent 2,375,384, granted to Erle T. Putnam of Detroit, and assigned to Libbey-Owens-Ford Glass Co.

Sheet and Plate Glass

In a machine for cutting glass sheets or plates, Joseph R. Morris of Toledo (2,375,378 to Libbey-Owens-Ford) has patented a combination of elements comprising a table for supporting the sheet, a template mounted above it, a cutting unit mounted upon and adapted to travel around the template, including a cutting tool for cutting and scoring the sheet, and means operated automatically by the cutting unit, when it reaches a predetermined position, for ejecting the sheet from the cutting table after completion of the cutting operation. Other patents on glass cutters are 2,377,098 and 2,377,099, granted to Wm. Owen of Pittsburgh and the Pittsburgh Plate Glass Co. These have reference to cutting units to be attached to mechanically operated apparatus.

Fig. 4 illustrates the proposal in patent 2,375,369 for overcoming windshield icing, particularly on aeroplanes. This invention of Milton Knight, Roy W. Wampler and Wm. J. Arner of Libbey-Owens-Ford consists of a special construction of double glazed windows with a centrally placed infra-red heating unit. The panes are laminated glass of which the inner sheet has high heat wave

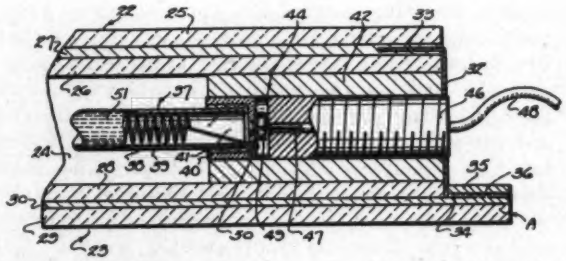


Fig. 4. Knight, Wampler and Arner : 2,375,369. To overcome icing of windshields an infra-red heater is placed within a glazing unit, the outer sheet of laminated glass being made of a heat absorbing composition.

transmission while the outer sheet has high heat absorbing properties so that it will become heated. Donald W. Dunipace of the same company also directed an invention toward solving a problem of the aerial gunner. In patent 2,375,352, he discusses the error in vision which occurs when sighting through a curved glass sheet. He concludes that this error is most nearly a constant when certain elliptical lines are followed in bending the glass and bases his patent on this discovery.

Two other Libbey-Owens-Ford patents are 2,375,349

(*Continued on page* 344)

GJ Research Digest

Practical Interpretations of Glass Technology

The Durability of Soda-Lime-Silica Glasses Towards Sodium Carbonate Solutions

M. A. Besborodov (*Journal Society Glass Technology*, April, 1944) has determined the durability towards boiling 0.1 N-Na_2 CO_3 solution of twenty-three soda-lime-silica glasses of compositions within the field of those in commercial use. The author states that the determination of the durability of window glasses should be based on the action of two reagents, namely, water and sodium carbonate solutions. The test of the durability towards water is advisable because of the exposure of window glass to rain, or to moisture in general; and of durability towards sodium carbonate solutions because the conditions of humid storage give rise to this substance. Between sheets of window glass packed in boxes there are small capillary interstices in which water vapor condenses with the atmospheric changes in temperature and moisture. And when moisture remains between the sheets for a long time, alkali is extracted from their surfaces. The sodium hydroxide solution formed in the first stages passes gradually into sodium carbonate solution, causing the corrosion during storage. The concentration of the sodium carbonate solution rises with time, thereby increasing the rate of corrosion. It is known that glasses sometimes have a high durability towards sodium carbonate solution, and vice versa. It is desirable that window glass be resistant to both.

The durability of the glasses was determined by a powder method, the grain sizes varying from 0.5 mm. up to 0.7 mm. The grains were carefully washed with alcohol, 10 grams weighed out and put into an Erlenmeyer flask of quartz glass with a condenser attached. The flask was charged with 250 $cm.^3$ of hot 0.1 N-sodium carbonate solution and boiled on a water-bath for an hour. The flask was then cooled, the solution poured off and the glass powder repeatedly washed with distilled water by decantation and once with dilute hydrochloric acid. The powder was then filtered and dried at 120°C. to constant weight. The test on each glass was repeated several times. From the results obtained, a ternary diagram for the durability of the glasses toward sodium carbonate solution was drawn up.

By comparing the results with those of G. Keppeler and H. Ippach relating to the durability to water, it was concluded that the glass of highest durability both to water and 0.1 N-sodium carbonate solution is that of percentage composition: SiO_2 75, CaO 10, Na_2O 15.

Variations of Refractive Index of Glass with Time and Temperature in Annealing Region

The properties and behavior of glass in the annealing region have been studied from many viewpoints in the last twenty-five years. Much theoretical work has been done on the anomalous behavior of such properties as refractive index, density, thermal expansion, strain and viscosity. These theoretical studies have borne fruit as the demand for high-precision optical glass has caused renewed interest in the behavior of refractive index during annealing. McMaster (*Journal of the American Ceramic Society*, January, 1945) reports on a study which concerns chiefly the manner in which the low index of a chilled or poorly annealed glass increases to equilibrium as it is important to know how the index increases during annealing when a high, stable and uniform value of index is desired for high-precision optical glass.

From the experimental work it was found that the refractive index of a rapidly cooled fiber of borosilicate glass increases according to the equation, $1/(N_e\text{-}N) - 1/(N_e\text{-}N_o) = A_t$, where t is time, N_e is equilibrium index, N_o is initial index, and A is a constant at constant temperature. Index data were plotted according to this equation to determine graphically values of N_e and A for several temperatures between 914° and 1060°F. Values of N_e for temperatures from 1060° to 1180°F. were determined by prolonged heating of the glass at each 20° interval. The change of A with temperature was found to be well represented by the equation, $\log A = K/T°C$, where T is the absolute temperature and K and C are constants.

In a practical application to annealing, this information can be used to calculate the time that must be spent at each temperature to reach a suitably high index with the shortest annealing cycle. It is sometimes more important to have a uniform index without necessarily reaching the highest value. Here, again, these data are useful in developing such a cycle.

These equations are also important from a theoretical point of view. Analysis of the data shows that the molecular reaction which causes the index to vary is not of the familiar, simultaneous, first- and second-order type.

PERSONNEL CHANGES AT FIBERGLAS

Owens-Corning Fiberglas Corporation recently announced several changes involving branch and division assignments designed to effect closer relationships with government procurement agencies and to expedite Fiberglas products to industries which incorporate Fiberglas into war materials and equipment.

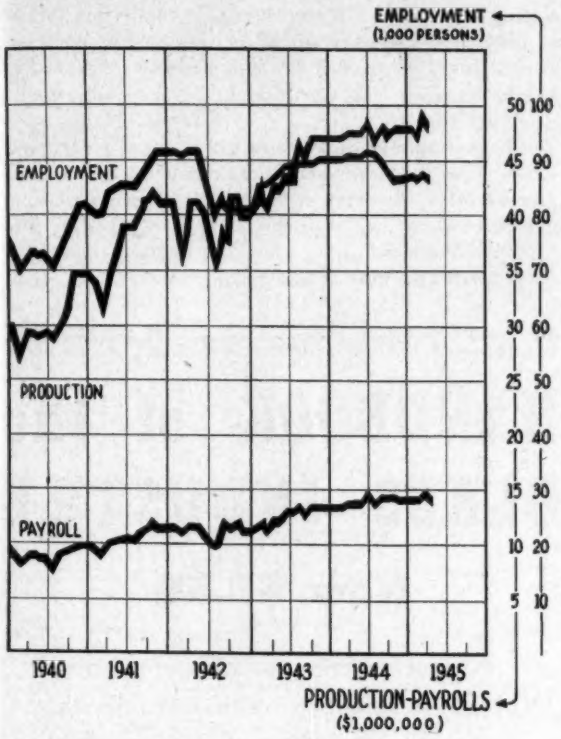
W. R. Sykes has been transferred to the Washington, D. C., office to be succeeded by M. W. Butler as Philadelphia branch manager. Mr. Butler formerly headed the Fiberglas Storage Batteries Division at Atlanta.

A. E. Kincaid, Jr., previously with the Washington office, returns to the corporation's general offices in Toledo as manager of the Shipbuilding Division. T. E. Butterworth, formerly at the Pittsburgh and Cleveland offices, succeeds Mr. Butler as specialist in charge of the Storage Batteries Division in Toledo.

CURRENT STATISTICAL POSITION OF GLASS

GJ THE GLASS INDUSTRY'S INDEX

Monthly Trends Through April, 1945



During April, activity in the glass industry dropped from the figures shown for the month of March. As reported by the Production Index, output for April was $48,000,000 as compared with $49,000,000 the previous month. This is the same figure that was reported for April, 1944. Production for the first four months of 1945 totalled $191,000,000.

Plate glass production for the month of May was 8,636,872 sq. ft. as reported by the Hughes Statistical Bureau. This shows an increase of slightly over 1 per cent above the previous month and a decrease of 8 per cent from May, 1944. For the first five months of 1945, a total of 42,399,990 sq. ft. was produced as compared to 41,898,337 sq. ft. produced during the same period last year.

Glass container production for May was reported at 9,295,495 gross—an increase of about 9 per cent above April and 4 per cent above May, 1944. During the first five months of 1945, glass container production totalled 42,158,446 gross as compared to 42,301,895 gross for the same period of 1944. The figure for 1945 shows a slight decrease from 1944. Total shipments reported for the first five months of 1945 were 43,395,932 gross.

Inventories on glass containers for May totalled 4,443,620 gross showing a very slight increase over April inventories. This figure compares with 4,709,931 gross reported for May, 1944.

Employment and payrolls: The number of employees in the glass industry during the month of April were 87,000. This compares with 88,300 in March and 92,600 persons in April, 1944.

Payrolls for April were $13,500,000 as compared with $15,000,000 in March. Glass manufacturers have paid approximately $57,500,000 in salaries during the first five months of 1945.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures Are in Gross)

		Production May, 1945	*Stocks May, 1945*
Foods; Medical & Health Supplies; Chemical, Household, Industrials; Toiletries & Cosmetics	Narrow Neck	3,021,348	1,915,705
	Wide Mouth	2,927,424	1,046,378
Dairy Products		305,890	271,856
Home canning		340,156	337,965
Beverages, Returnable		732,149	383,232
Beverages, Non-Returnable		—	—
Beer, Returnable		653,103	94,942
Beer, Non-Returnable		453,014	41,310
Liquors		578,055	260,141
Wines		188,862	75,341
Packers' Tumblers		95,494	16,750
Total		9,295,495	4,443,620

GLASS CONTAINER SHIPMENTS

(All Figures Are in Gross)

	May, 1945
Narrow Neck Containers	
Foods	701,435
Medical & Health Supplies	1,002,066
Chemical, Household, Industrials	591,361
Beverages, Returnable	684,740
Beverages, Non-Returnable	—
Beer, Returnable	624,719
Beer, Non-Returnable	441,572
Liquors	578,811
Wines	204,816
Toiletries & Cosmetics	517,623
Sub-Total (Narrow Neck)	5,347,143
Wide Mouth Containers	
Foods	2,331,763
Dairy Products	302,499
Home Canning	372,249
Medical & Health Supplies	312,055
Chemical, Household, Industrials	128,872
Toiletries & Cosmetics	176,494
Packers' Tumblers	97,996
Sub-Total (Wide Mouth)	3,721,928
Total Domestic	9,069,071
Export Shipments	200,688
Total Shipments	9,269,759

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Automatic tumbler production for May totalled 5,879,960 dozens, representing an increase of about 24 per cent over the preceding month of April. Production for May this year is only slightly less than the figure reported for May 1944. Shipments of automatic tumblers during May totalled 5,566,235 dozens as compared to 5,124,409 dozens in April and 5,850,840 dozens shipped during May 1944. Finished stocks on hand as of the end of May were 4,584,433 dozens as compared to 7,600,059 dozens for May of last year—a decrease of about 39 per cent.

Table, kitchen & household glassware: Manufacturers' sales of machine-made table, kitchen & household glassware for May were reported at 2,405,487 dozens, as compared to 2,795,570 dozens shipped in April. However, the May 1945 figure showed a slight increase over that reported for May of last year.

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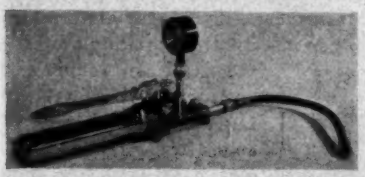
NEW EQUIPMENT AND SUPPLIES

PRESSURE GAUGE TESTER



Mansfield & Green, Cleveland, Ohio, has announced the development of a new multi-purpose pressure gauge tester. It combines for the first time in a single unit a pressure gauge tester that can be used with equal facility for bench testing and for portable testing in the field. On bench testing, the unit can be used with test gauges or with a dead weight attachment.

A simple, doubly-sealed check valve completely eliminates leakage and loss of pressure even with grit in the system, whether using oil or water or pressures up to 10,000 p.s.i.

Principal uses of the testing unit include testing and repairing of pressure gauges and instruments, the setting of relief or other pressure actuated valves and general hydrostatic testing.

IONIZATION GAUGE

Precision Scientific Company, 1750 N. Springfield Ave., Chicago, Illinois, announces the "Precision-Televac" Ultra Vacuum Gauge, known as Type E-31. Electrical leakage is completely eliminated and, when used with a moderately high speed pumping system, the ionization gauge outgasses itself. Filament is protected before and during operation automatically since current will not enter filament before pressure of 1 micron has been established and turns off automatically if pressure rises above 1 micron.

Gauges are interchangeable without recalibration and guaranteed for 1,000 hours. Standard E-31 ionization gauge comes on scale at 0.4 micron and is used with the Televac type "S" recorder. Write for copy of the new bulletin 450R illustrating and describing the complete line of "Precision-Televac" high vacuum instruments.

NEW TYPE GAS ANALYZER

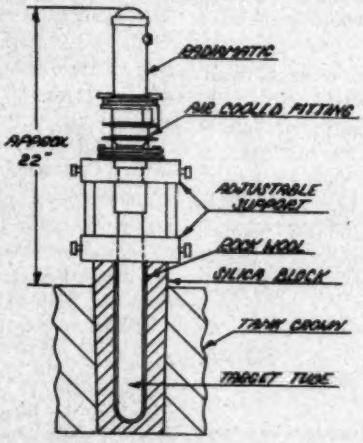
The Hays Corporation, Michigan City, Indiana, reports the development of a special analyzer for testing the high purity of oxygen, carbon dioxide and nitrogen in the range from 90% to 100%.

The new analyzer, known as the Hays Series "E," was developed as a result of the demand for testing the high purity of oxygen in flying and other war essentials. It is offered in two styles—a wall mounted model for permanent installation and a portable model in a metal case with leather carrying handle. It may be had with a single unit or with two units and is available in a junior model (Series EJ) with a burette capacity of 30cc. A bulletin giving details is available upon request (Pub. 45-743).

BROWN INTRODUCES NEW SILICA BLOCK

Brown Instrument Company, Philadelphia, Pa., has developed a new silica block for measurement of crown temperatures in glass tanks for use with Radiamatics, radiation pyrometers.

The new silica block is said to have three additional advantages, namely: 1—More constant calibration than is usually experienced with thermocouples. 2—More open scale divisions throughout the operating range. 3—Lower net cost. The increased service life of the Radiamatic and its new accessories will more than offset additional initial costs. The single hole silica block, according to reports of the Brown division of Minneapolis-Honeywell Regulator Company, is installed flush with inside roof surfaces. It is sometimes installed so that the bottom of the block extends into the furnace for several inches. The Radiamatic is sighted into an 18-inch Sillimanite target tube which is in-



stalled in the block to within one-quarter inch of the bottom. An air-cooled fitting only is necessary to prevent overheating of the Radiamatic under normal operating conditions. The target tube is maintained under a slight positive pressure by connecting to a low pressure air supply.

The Sillimanite target tube is accurately positioned by adjustment of the vertical support. The annular opening between the Sillimanite tube and the silica block is packed with rock wool or similar material to prevent accumulation of batch dust.

CATALOGUES RECEIVED

General Electric Company, Schenectady, N. Y., is distributing two recent publications. One is Bulletin GEA-4254 and contains information on and illustrations of Push-Button Units, Selector Switches and Indicating Lights for built-in (machine-tool) applications.

The second booklet is Bulletin GEA-4363, containing information on Thickness Gages to Measure Thickness of Nonmagnetic Materials. Both of these bulletins are profusely illustrated with charts, diagrams and photographs of the equipment covered.

The North American Philips Company, Inc., 100 East 42nd Street, New York 17, New York, has just announced the issuance of a new 8-page illustrated booklet describing the "Geiger-Counter Spectrometer for Industrial Research."

The booklet contains a detailed discussion on the theory underlying X-ray powder diffraction. The performance and applications of the Norelco Spectrometer, Geiger-counter tubes, circuits and losses are also covered at some length, and photos, diagrams and curves are included for illustration purposes. The article was reprinted in booklet form by permission of the Navy Department.

The B. F. Goodrich Company, Akron, Ohio, has published a 22-page booklet on the Lonn rubber blow and spray guns and water savers. Photographs and charts throughout help explain and illustrate the Lonn equipment.

The booklet explains the principle of Lonn valves which have only three working parts and give constant finger-tip control of air or water under pressure without the use of levers, springs, push buttons, packings or screws. It is also shown how elimination of small parts reduces repair and replacement problems and results in low maintenance costs.

Attachments, among them the spray gun conversion unit, are described and each of the Lonn guns is pictured, its application outlined and other pertinent details given.

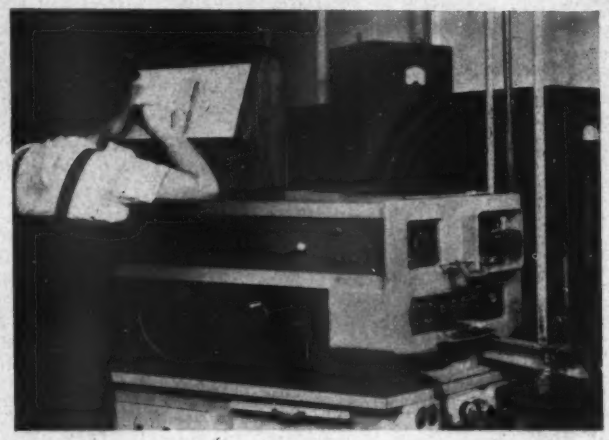
The Wheelco Instruments Company, Harrison and Peoria Streets, Chicago, Illinois, has recently released a new 12-page catalog on "Wheelco Electronic Controls."

The company has designed the bulletin to offer a convenient, condensed listing of the principal items of equipment they supply. Also described is their electronic principle by which control is effected without contact between measuring and control units of an instrument. Brief descriptions and prices are included of indicating pyrometers and pyrometer controllers, indicating resistance thermometers and resistance thermometer controllers, input controllers, program controllers, portable potentiometers, combustion safeguards and thermocouples.

ARMSTRONG'S GLASS RESEARCH . . .

(*Continued from page* 323)

The Physics Department provides very complete equipment for glass research and testing. For viscosity studies, a high temperature concentric cylinder viscometer is available.[2] A fiber viscometer for measuring the viscosity of glass in the annealing range, and a softening point furnace also are used. The viscosity data have supplied valuable information in the study of glass compositions. By working out the component oxide factors, it is possible to predict the viscosity of a new glass composition from the viscosity measurements of glasses which have been studied previously.



Spectograph and viewing stand used in glass analytical work.

Spectrographic equipment holds interesting possibilities in the glass field and methods for quantitative analyses of minor ingredients in glass are being investigated.

Visual and infra-red spectrophotometers likewise are expected to be of considerable value in the study of color and heat and light transmission of glass. The usefulness of these instruments is obvious in the study and improvement of ambers and other colored glass.

One of a number of machines and instruments available for use in glass research is a universal testing machine which is employed for compressive or tensile strength studies on a wide variety of products and materials ranging from 105 mm. shells, to glass bottles, to crown cap liners. This equipment can be controlled to exert loads from one-half pound to 100,000 pounds.

A very complete high frequency unit has been installed for experimental work in connection with molded closures and other products.

2 "Viscosity of Recent Container Glass," Jl. Am. Cer. Soc. 27:129 (1944).

Much of the specialized equipment and gadgets needed in the Armstrong Laboratory are built in the Laboratory's Shop, or in the Company's Engineering Shops.

Constant temperature and humidity rooms (70 degrees F. and 50 per cent relative humidity) are maintained for standardized physical testing. In another controlled room, simulating tropical conditions, temperatures of 100 degrees F. and 95 per cent relative humidity are provided. This room has been most useful in studying the weathering characteristics of glass and glass containers. The Laboratory also has a room simulating desert conditions which operates at 120 degrees F. and 10 per cent relative humidity in which dry, high-temperature storage can be studied.

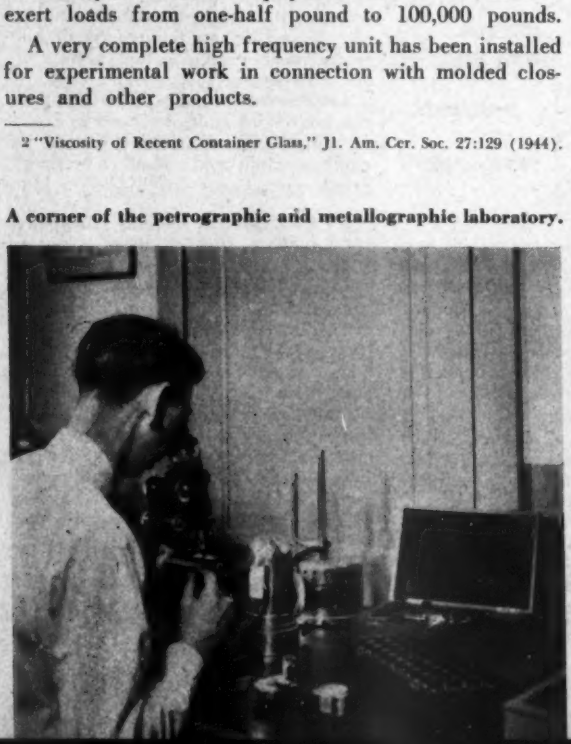
An important adjunct of the Laboratory is its Technical Library which is in charge of a librarian trained in chemistry and in library practice. The shelves now hold about 3,000 volumes, including all the standard chemistry and physics texts and reference works in English, German and other languages. The Library is playing an increasingly important part in the work of the Laboratory and it is normal practice for an Armstrong chemist or physicist, when assigned a new project, to search the literature thoroughly before starting actual experimental work.

Control laboratories, which form the connecting link between the production units and the research and development work at Lancaster, are maintained in Armstrong's sixteen domestic plants. The staff in the plant laboratory at Millville serves not only as an operating laboratory but also conducts plant development and plant investigations for both of Armstrong's glass factories.

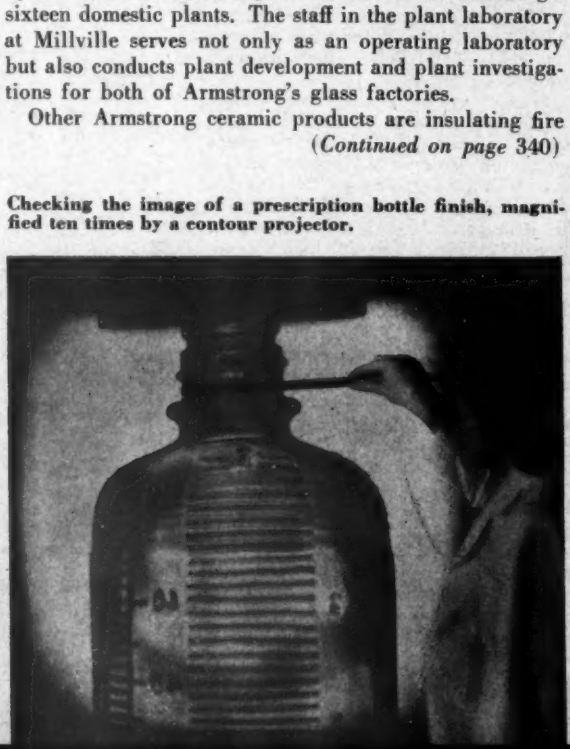
Other Armstrong ceramic products are insulating fire

(*Continued on page* 340)

A corner of the petrographic and metallographic laboratory.



Checking the image of a prescription bottle finish, magnified ten times by a contour projector.



(*Continued from page* 326)

Figure 6 represents a contact print of the seven microscope slides whose data are presented in Table VI. This figure shows very clearly that a low temperature metakaolin treatment leading to a hydrogen glass increases the reactivity toward cuprous chloride, but metakaolin treatment at 550°C. makes the glass practically inert. Around 450°C. the two effects are nearly balanced.

When the metakaolin treatment has no effect on the reactivity of the glass surface, the ratio between treated and untreated area is 1.0. Values lower than 1.0 indicate that the metakaolin treated area has assumed higher reactivity and accumulated more cuprous ions during the subsequent base exchange process. Values larger than 1.0 indicate that the metakaolin treated surface has become less reactive so that during the cuprous chloride exposure, a smaller amount of cuprous ions was able to enter the exchange reaction.

The variation of R with temperature might be interpreted in the following way: Above 450°C. the steep increase of R is no doubt the result of Na_2O removal from the glass surface. This process becomes significant at a temperature where the oxygen ions begin to migrate with noticeable speed. At room temperature and slightly above, the reaction rate between kaolin and glass is too slow to produce effects which could be detected by our method. Above 200°C., however, a base exchange reaction between hydrogen clay and sodium glass leading to a hydrogen glass increases the chemical reactivity. The result is a glass with a darker spot. Around 300°C. the glass has reached its maximum reactivity and above this temperature the removal of H_2O from the hydrogen glass makes the surface more inert to the cuprous chloride vapor. Around 400°C. treated and untreated glass surface can no longer be distinguished because in this temperature range, the positive and negative effects counterbalance each other. Above this temperature the strong influence of the dealkalization process just mentioned dominates the picture.

(3) The Thallous Chloride Test: Another test shall be described which in itself does not give more or better information than the previous test, but indicates that cuprous chloride is by no means unique in its behavior to a glass surface. This test is carried out in exactly the same way as the former only thallous chloride takes the place of cuprous chloride. So far as the bloom formation is concerned, the phenomenon is exactly the same. Bloom indicates the replacement of Na^+ by Tl^+. The formation of Tl^+ $Glass^-$ is recognized by its strong bluish-white fluorescence, when irradiated with filtered short wave ultra violet. Again this method gives only semiquantitative results, because the intensity of the fluorescence is not an exact measure of the Tl^+ ion concentration. It might very well be that the fluorescence center is not the thallous ion itself, but the thallium atom which could form according to a disproportionation of the thallous silicate glass.

$$3Tl^+ \rightarrow Tl^{3+} + 2Tl$$

Even if we knew for certain that the thallous ions are the carriers of the fluorescence, concentration quenching would mask a simple relationship between fluorescence intensity and Tl^+ concentration.

(4) The Silvering Test: E. C. Marboe and W. A. Weyl[20] recently advanced the picture that for a certain group of mirroring reactions, the first step in the deposition of silver or copper is a base exchange reaction between Ag^+ or Cu^+ and Na^+ and not a mere adsorption of a heavy metal compound at the surface. The theory that the glass surface actually participates in the chemical reaction leading to a metal deposition explains certain observations which otherwise could not be readily understood. Everybody who ever attempted to silver or copper a glass surface knows how important the treatment of the glass is which precedes the actual mirroring process. K. Nakanishi[28] who made an extensive study of the effect of heat treatment of glass upon silver plating found that the best mirrors were obtained when, previous to the plating process the glass had been heated for an hour to a temperature 50-100° below its softening point. Recalling our discussion at the beginning of this paper, we find that such a treatment causes alkali to migrate to the surface under the influence of surface tension. It is well known that glasses with a higher alkali content are more suitable for silver plating than low alkali glasses.

Based on this experience a study was undertaken to find out whether or not silverplating could be used to differentiate between our treated and untreated glass surfaces. For this purpose a freshly prepared mixture of an ammoniacal silver nitrate solution and a glucose solution was used. In order to bring about the difference between high and low alkali areas, the usual stannous chloride treatment had to be omitted.

Dilute ammonia (4%) was added to a 1% silver nitrate solution until the precipitate of silver hydroxide which first forms had dissolved. Excess of ammonia has to be carefully avoided. To five parts of this silver solution one part of a 2% glucose solution was added. This freshly prepared mixture was poured on the glass surfaces to be tested, and the times were measured until the first metal deposit had formed. In order to give comparable results, the temperatures had to be accurately controlled. For this purpose the silvering operation was carried out in a box, having a glass bottom and glass lid. The temperature was controlled by a heating coil and inside thermometer. If other factors were kept constant the time required to form the first visible silver deposit was found to increase with progressing dealkalization of the glass surface.

C. *Tests based on the Mechanical Stress introduced by the Dealkalization of the Glass Surface*

Up to this point, only such methods were discussed which were based on the chemical differences between the normal and the dealkalized glass surface. As these surfaces must also differ in all their other properties one might just as well use optical or mechanical properties in order to differentiate. This paragraph deals with the mechanical forces set up in a dealkalized glass due to the difference in expansion of the dealkalized layer and the bulk of the glass. The process of dealkalization takes place at a temperature of about 500°C. As a first approxima-

(*Continued on page* 341)

ARMSTRONG'S GLASS RESEARCH . . .
(*Continued from page* 338)

brick and related materials. The Laboratory at Lancaster has a pilot brick plant which includes a mixer, press, drying oven, and kiln, all of which equipment is accurately controlled. As indicated previously, the Physics Department is fully equipped to evaluate the tested bricks, to determine thermal conductivity and other physical properties.

To supplement the work done in its own laboratories, Armstrong supports fellowships in several research institutes, and the Company has arrangements in effect with a number of colleges and universities under which assigned research projects are being carried on by faculty members who were enabled to accept outside work because of war-reduced student enrollments. Several of these supplementary research projects deal with glass.

The advantages of Armstrong's diversification of products are numerous and they are certainly evident in the Company's research program. The glass chemists, for example, have constantly available for consultation organic and physical chemists from the Floor, Munitions, Building Materials, and Industrial Division Sections of the Laboratory, which are counterparts of the Company's other selling Divisions. The intimate relationship between glass and closure research has been indicated. Some of Armstrong's other products, besides insulating fire brick, are also closely allied to the glass industry, and research projects in these related fields naturally complement each other in greater or less degree. But the projects of chemists working on products which superficially have little in common with glass can sometimes shed light on a ceramic problem, and conversely, some phase of Armstrong's glass research occasionally is applicable in other fields.

Armstrong's research laboratories are administered by a Director of Research who is a Director of the Company. The research budget for 1944 was the largest in the Company's history, the 1945 budget is even larger, and laboratory personnel is at an all-time high. Armstrong considers research a highly important element in its planning for post-war progress.

MATHIESON ANNOUNCES NEW TECHNICAL APPOINTEES

G. W. Dolan, President of The Mathieson Alkali Works, has announced the appointment of G. P. Vincent to the newly created position of Technical Director. Dr. Vincent was formerly Manager of the Sales Development and Technical Service Department.

R. E. Gage, whom Dr. Vincent succeeds, has been appointed Technical Adviser of the company. Mr. Gage was Director of Research and Development for The Mathieson Alkali Works for fourteen years. Both men have been very active in the invention and development of various processes of manufacture during their years of association with the Mathieson company.

SYLVANIA LIGHTING CENTER OPENED IN NEW YORK

At the recent opening of its new Lighting Center, Sylvania Electric Products, Inc., introduced modern, fluorescent lighting styled especially for the home. Months of research by company engineers, stylists, architects, working with a noted design consultant, resulted in the presentation of a group of rooms revealing lighting that is as decorative as it is efficient.

The Lighting Center provides the company with a laboratory for experimenting with new residential lighting ideas and evaluating them over a sufficient period of time in their normal surroundings.

The company's goal in decorating and lighting the rooms was to avoid flat panels, boxlike fixtures and overemphasis on efficiency. The rooms are functional because they provide good lighting and enough of it with a high degree of eye comfort. The purpose to which each room would be put and other similar factors were taken into consideration and the proper source of illumination installed for each use.

One of the outstanding features of the rooms is the successful use of both fluorescent and incandescent light sources. Both were used in the living room and bedroom and the combination presents a soft, pleasing effect as well as providing adequate light for any task.

In the kitchen continuous strips of fluorescent lamps have been mounted on the ceiling over the work surfaces. The unit follows the contour of the surfaces with light coming down on the areas where food is prepared.

In the model bathroom, lamps on either side of the mirror provide excellent illumination for shaving or applying make-up because the long lines of light reach from the top of the head to below the chin, thus eliminating the shadows usually created under the chin.

SURFACE DEALKALIZATION OF FINISHED GLASSWARE . . .

(*Continued from page* 339)

tion we might disregard the fact that it establishes a sodium ion concentration gradient and assume that from a certain surface layer, as a whole, 50% of the Na_2O is removed. This leads to a layer of glass with a lower thermal expansion. On cooling, this surface layer, therefore, tends to contract less than the bulk of the glass. In order to demonstrate the effect we start with a high alkali glass of chemical composition: 72% SiO_2, 20% Na_2O and 8.0% CaO. The coefficient of expansion of this glass can be calculated on the basis of Winkelmann and Schott's Factors for the three oxides:

SiO_2	72.0%	$72.0 \times 0.27 \times 10^{-7}$	=	19.4×10^{-7}
Na_2O	20.0%	$20.0 \times 3.33 \times 10^{-7}$	=	66.6×10^{-7}
CaO	8.0%	$8.0 \times 1.67 \times 10^{-7}$	=	14.4×10^{-7}
Its linear coefficient of expansion is				100.4×10^{-7}

Taking a surface layer of this glass and removing exactly one half of the Na_2O and remelting the rest give us a glass of the following composition and expansion:

SiO_2	80.0%	$80.0 \times 0.27 \times 10^{-7}$	=	21.6×10^{-7}
Na_2O	11.2%	$11.2 \times 3.33 \times 10^{-7}$	=	37.3×10^{-7}
CaO	8.8%	$8.8 \times 1.67 \times 10^{-7}$	=	15.8×10^{-7}
The linear expansion is now				74.7×10^{-7}

Let us assume that this glass at room temperature is 450°C. below its setting point. That means below 475°C. we have no yield and the difference in the expansion or better contraction must result in stresses set up between the two glasses. The difference in contraction is

$$d = 100.4 \times 10^{-7} - 74.7 \times 10^{-7} = 25.7 \times 10^{-7}$$

inches per inch for each degree C.

From the setting point to room temperature this amounts to

$$450 \times 25.7 \times 10^{-7} \text{ inches per inch} = 1.16 \times 10^{-3}$$

When the dealkalized glass has reached room temperature there should be a difference between the surface layer and the bulk of 1.16×10^{-3} inches for every inch of glass.

As it is impossible for the surface to contract less than the bulk, we can calculate the approximate strain in the surface layer as follows. Each inch of the surface layer is compressed by the bulk to 1.16 thousands of an inch. If we assume a surface layer of only 1/100 of the total thickness of the ware we can say that practically the whole deformation is carried by the surface which is in a state of compression. Compressing an inch of glass by 1.16 thousands of an inch requires about

$$1.16 \times 10^{-3} \times 10^{7} \text{ (Youngs Modulus)} = 11{,}600$$

lbs./sq. inch

A compression of 11,600 lbs./sq. inch must lead to a considerable deformation even if it is restricted to a small fraction of the thickness of the ware. This could be demonstrated by the ring test.

From a tumbler a ring was cut of approximately 2½ inches diameter and 1/16 of an inch wall thickness. The ring was annealed and cut open. The opening was 1/16 of an inch. Then the open ring was covered with a clay slip on the inner surface only and heated for several days at 550°C. in order to get sufficient depth action. After cooling the ring was found to have opened 1/16 of an inch more, which means that a considerable deformation had taken place.

With other ring sections which had been dealkalized at the inner, the outer and on both surfaces, the resulting stresses were studied by means of the polarizing microscope. Even if a treatment produced strong strains, no birefringence could be detected when examined perpendicular to the surface. This indicates the presence of isotropic strains which are laminar and highly symmetrical.

Effect of Dealkalization on the Properties of Glass

The effects which the dealkalizing process has on the properties of glass can best be described by dividing the treatment into three parts, according to the temperature, and discussing their effects separately.

A. *Low temperature treatment*

Up to about 300°C. the reaction between glass and clay leads to a "hydrogen glass." When this reaction starts has not yet been exactly determined. At 150°C. one obtains very striking changes, but there can be no doubt that sensitive methods would reveal base exchange even at room temperature.

B. *Medium temperature treatment*

Without having a sharp demarcation line, this second step begins with the evolution of H_2O from the hydrogen glass. On heating the glass fairly rapidly, we might neglect the first stage (base exchange) completely, and describe this stage as that of alkali removal below the strain point. Its upper limit is given by the temperature where the glass yields to the stresses set up between surface layer and bulk of the glass. The difference in composition produces a difference in the amount which the glass contracts on cooling. Staying below the strain point, the exact temperature of which is a function of time, prevents warping and formation of a wavy surface.

C. *High temperature treatment*

There is no fundamental difference in the chemical reaction which leads to the removal of alkali at temperatures above the strain point. Although the rate will be increased, there is danger that it will be difficult to remove the coating. On cooling from temperatures above the strain point, however, we have to expect deformation of the glass piece—especially wavyness of its surface because the surface contracts less than the bulk of the glass. Below the strain point the difference in contraction leads to the surface layer being in a state of compression; above the strain point, however, a part of the stress is released and causes deformation of the surface. In our experiments 550°C. was about the safe limit for the soda lime glasses used. Samples which had been dealkalized at 600°C. always showed a wavy surface.

On this basis the proper treatment for a specific purpose can be selected. The high temperature reaction, being by far the most rapid and efficient will only be

applicable where the surface condition of the glassware is of secondary importance. The medium temperature treatment accomplishes the same effect in longer times without disturbing the surface texture. Medium temperature treatments are best suited for increasing the resistance of the surface toward chemical attack. The low temperature treatment on the other hand may be useful whenever increased surface reactivity is desired.

There is a difference in structure between hydrogen glass surfaces obtained by the method of dealkalization described in this paper and the acid leached surfaces. The acid attack will often remove all the basic constituents and leave just the hydrated silica skeleton. Our method is restricted to the substitution of H^+ ions for the alkali ions only. Ca^{++} or Mg^{++} ions will not be affected. Another fundamental difference results from the different temperatures where both processes are carried out. The acid leach is a typical low temperature process, taking place between room temperature and the boiling point of water. In this temperature range the diffusion of Na^+ ions is slow and as a result we obtain a sharp demarcation line between the unaltered and the hydrogen glass. This sudden change in turn causes a discontinuity in the refractive index of the glass and has therefore been used to develop low reflection films. Our method will not produce such an effect because at around 350°C. the place exchange between H^+ and Na^+ has become so fast that a sharp transition between glass containing H^+ and the original containing the Na^+ is not possible any more. The refractive index will gradually change from that of the H^+ glass to that of the Na^+ glass.

The hydrogen glass prepared by our method might find a field of application where increased reactivity is desirable. Modern developments in glass technology make more and more use of combinations between glass and plastics. Laminated safety glass, plastic mats reinforced by glass fibers, and the water repellent coatings obtained by treating glass with organic silicones, are typical examples. For these purposes it is important that good contact and adherence are obtained between the glass and the organic material. A hydrogen glass might be advantageous for this purpose. Hydrogen glasses treated with methylchlorosilane or similar compounds, produce a strong bond between the silica network proper and organic groups. Such a bond has been used to produce water repellent films. ("Dri-Film" is the trade mark of the General Electric Company's water repellent compounds based on this principle.) The same surface reaction might also be used to improve the adherence between glass and plastics in fiber glass mats and laminated safety glass.

For the present time our interest shall be focused on the dealkalization of glass below the strain point. From the methods which were used to follow this reaction, especially from the results obtained by the accelerated acid resistivity test, one learns that dealkalization leads to a quite unexpected increase in chemical resistivity. This improvement already offers a possible field of application. It is true that for most purposes our commercial soda lime glasses have sufficient chemical resistivity. However, the high requirements of the glass trade can be met only if the glass industry, especially the manufacturers of bottles and special containers, compromises with the meltability of the glass. As a rule the good chemical qualities of this group of glasses is the result of lower alkali and additional alumina. Both changes increase the melting and fining temperature of the glass, which in turn makes the process much more expensive. It not only increases the fuel consumption but is also harder on the refractory materials and reflects on the homogeneity of the glass.

Let us assume a manufacturer making a certain type of container which does not have to meet the strictest requirements wants to produce, in addition to this ware, another type which is subjected to more rigid tests for chemical resistivity. If the market for the last article is not large enough to warrant an additional melting unit for a more durable glass, the composition of his glass has to be changed according to the requirements of the minor article. Such a change might upset the financial gain. In this case dealkalization of a part of the ware would be the solution.

The fusibility of the glass surface is closely connected with some of the electrical properties. Experiments to determine the influence of the dealkalization of glass on the electric surface leakage are under way and we have all reason to expect that stabilizing the glass by dealkalization will produce a considerable improvement of this property. In the meantime some preliminary experiments were carried out which demonstrate clearly the order of magnitude of the expected improvement.

The electrical conductivity of small test tubes made from soft glass tubing 12 mm. in diameter and 1.2 mm. wall thickness, was measured as a function of the temperature. The tube was filled with a conducting melt of either metal or sodium nitrate and inserted into a bath of the same conductor. In order to obtain comparable results the tubes were filled to a height of one inch each. The electrical resistance was measured with an alternating current between 230 and 400°C. Below 230°C. the resistance was too high to give reproducible values with our method and above 400°C. the reproducibility was impaired by the self-diffusion of alkali ions which changed the structure of the dealkalized glass layer. Within this temperature range, however, the reproducibility was very satisfactory. The results are summarized in Table VII:

TABLE VII

	Glass	Glass Treated with Metakaolin at 500°C.	
Temperature	Untreated	16 hours	26 hours
230°C.	99,000	180,000 ~	230,000 ~
250	50,000	61,000	73,000
300	9,000	11,000	15,300
350	2,000	2,700	3,900
400	830	940	1,270

Using these values and assuming that the metakaolin treatment produced dealkalization of a surface layer between 0.1 and 0.01 mm. thickness, we can calculate the approximate resistivity of the dealkalized layer as compared with that of the bulk of the glass. We found that the electrical resistivity of the dealkalized glass was about one hundred times that of the bulk of the glass.

In electrical insulation the bulk property of the glass is of minor interest. Electric leakage is practically always connected with the formation of a surface film of

(*Continued on page* 344)

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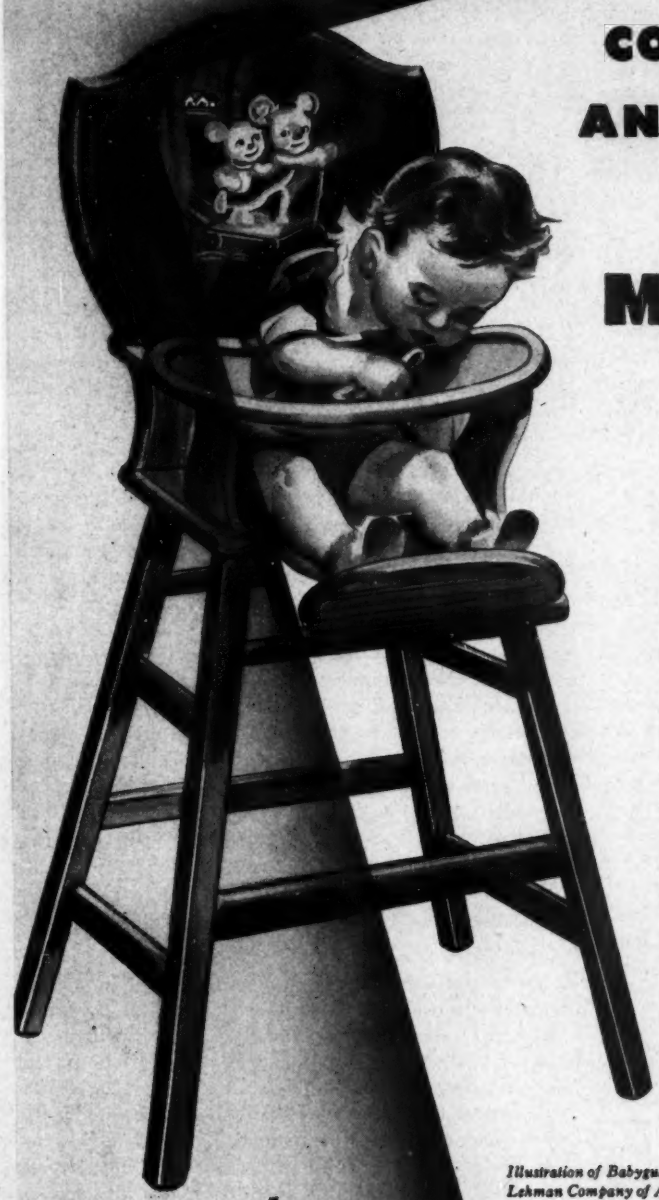

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SURFACE DEALKALIZATION OF FINISHED GLASSWARE . . .

(*Continued from page* 342)

lower resistivity. This opens another application for the metakaolin treatment; treatment of soda lime glasses to improve the electrical insulating properties. The fact that dealkalization increases the electrical resistance about one hundred times and at the same time improves its chemical resistivity should make it valuable for improving glass insulators.

In a subsequent publication, a detailed discussion will be given of the effect of the dealkalization on the strength of glass. There are good reasons for expecting this process to influence favorably the mechanical strength, especially the fatigue strength of glass due to the formation of a surface layer prestressed under compression.

If we restrict our interest to the application of the metakaolin process below the strain point, we may very well derive the properties of the treated glass surface from those changes which are brought about by lowering the alkali content of a glass. For some practical applications it might be of interest, however, to know what happens to the dealkalized glass surface on heating to temperatures within or above the softening range. Such additional heat treatment might be necessary for fusion of glass to glass or for glass to metal seals.

One phenomenon arising from heating above the strain point has already been mentioned: warping of the surface.

In addition we might expect the glass to devitrify if the heating is extended for a long period. That was observed by G. Bulle and A. Dietzel[29] when they reheated glassware which had been annealed in an open lehr. As pointed out in an earlier part of this paper, furnace gases when reacting with the glassware during the annealing operation cause removal of alkali. After the bloom of sodium sulfate had been washed off, the ware was perfectly clean and had a smooth surface. Reheating, however, produced cloudiness of the surface and it was found by these authors that this defect was the result of the formation of tiny crystals of cristobalite. We have to expect the same thing to happen if dealkalized glasses are subjected to an additional prolonged heating.

It goes without saying that prolonged heating at temperatures above the softening point must destroy the effects of the metakaolin treatment because it causes new alkali ions to diffuse into the surface layer. In the beginning of this paper we pointed out that migration of the alkali to the surface due to surface tension takes place even below the strain point. Our experiments indicate no deterioration due to alkali migration even at 500°C. The explanation is that Na^+ ion can only migrate by jumping from its own place to that of a neighboring Na^+ ion. It can change places with H^+ or with another Na^+. If now the glass surface is composed of a layer which is practically devoid of sodium ions no such ions can penetrate through this layer, at least not in a temperature region where the breakage of major bonds is a rare event. The failure of Na^+ ions to diffuse through a silicate glass which does not contain monovalent ions has its analogue in the electrical conductivity of quartz parallel with and perpendicular to the c-axis. The structure of the quartz provides channels for the sodium ions—which constitute a common contamination of even the purest rock crystals—but only in the direction of the c-axis. In other directions Na^+ ion cannot squeeze its way through the crystal. From this point of view dealkalization not only improves the electrical insulating power of glass, but at the same time, prevents its deterioration with time at elevated temperature.

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27. E. Berger, Glastechn. Ber. *12* (1934) 189-198.
28. K. Nakanishi, Journ. Soc. Chem. Ind. Japan *36* (1933) 595B-596B and 672B-673B.
29. G. Bulle and A. Dietzel, Sprechsaal *69* (1939) 358-359.

INVENTIONS AND INVENTORS . . .

(*Continued from page* 333)

to Wm. P. Collins of Toledo for a storm window, and 2,375,396 to George B. Watkins, also of Toledo, for the application of a temporary coating of powdered sugar to a specific type of plastic sheeting to facilitate its handling.

Another patent on laminated glass having an outer extension of the plastic layer which can be used in mounting the sheet, is 2,377,084, assigned to Pittsburgh Plate Glass Co. by Leroy D. Keslar of Tarentum, Pa.

Frederick W. Adams of the Pittsburgh Plate Glass Co. has received another patent, 2,377,062, in his field of work where he is seeking to produce a silica enriched glass surface so as to increase its resistance to scumming upon exposure to weather. In effect he merely accelerates the scumming action as an extra manufacturing step and then removes the scum. Specifically he exposes the surface to virtually saturated air for several days with the glass hot enough to be above the dew point; after this has served to leach some of the alkalies and alkaline earths from the surface layers and has formed a scum, the final step is to remove the scum with dilute acid.

Glass Wool and Fiber

Fiber patents included 2,376,698 to Jan S. Irvine and Raymond F. Clark (Owens-Corning Fiberglas Corp.) for reinforcing fibrous board in an area which is to receive a screw or other fastener, which consists of forcing a hardenable plastic material into this area. Johns-Manville was assignee of Harold T. Coss' patent 2,375,284 for a means of making fibrous nodules from previously felted mineral wool, and also of 2,376,043, issued to F. C. Freeman and A. B. Rieger for a means of splitting the stream of mineral slag issuing from a furnace so that several streams may simultaneously be blown into fibers.

• Erwin C. Hoeman, chemical engineer, has joined the staff of Battelle Institute, Columbus, Ohio, where he will be engaged in chemical and ceramic research. Mr. Hoeman was formerly associated with the U. S. Bureau of Mines at Rolla, Missouri.

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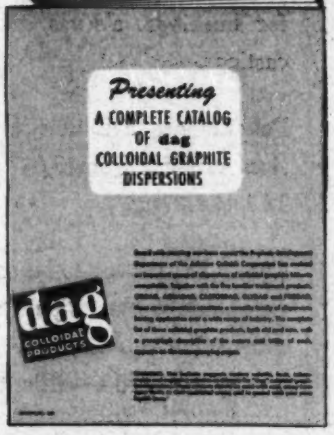

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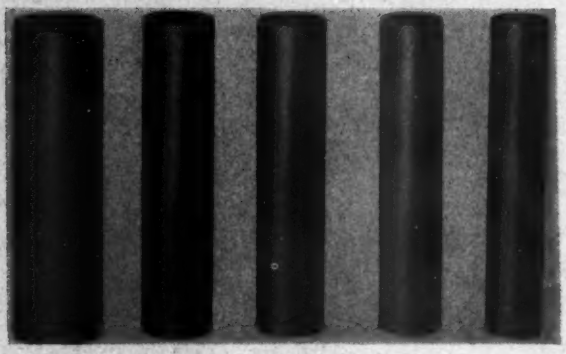

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THE FINISH GAUGE—LATEST CONTRIBUTION TO GLASS CONTAINER QUALITY CONTROL . . .

(*Continued from page* 327)

the finish should be wiped with gloves or bare hands. This wiping is essential in order to smooth the harsh, dry, original glass surface so that it can be readily gauged.

The container under examination is placed on a flat surface, such as a bench top or surface plate. The gauge is then placed on the container with the trigger guard and indicator zero pointing away from the inspector or gauger. While the gauge is held steady with one hand the container is rotated with the fingers of the other hand. As it is turned, maximum and minimum diameters are read directly from the dial and may be directly related to mould parts position; actions or sizes which may have affected finish dimensions.

Referring again to Figure 1, the jar shown measured plus 4 and minus 2. The mean or average diameter is midway between maximum and minimum or plus 1 in this instance. A reading such as this indicates an exceptionally good container, well within standard tolerances, only six thousandths out-or-round and is of ideal average diameter. Since such measurement also indicates a smooth sealing surface, without off-sets or indentations, it offers an ideal circumference for a perfect cap seal.

Fig. 2.

Standard tolerances and practices have been built into the H-E Finish Gauge in the following manner. In the case of the 1710-48 baby food finish for example, the standard maximum for the master gauge is 1.890 and is so marked. The master gauge is calibrated to the working Finish Gauge so that the standard maximum is indicated as plus 15 and the standard minimum will be minus 15. The perfect mean average will thus be zero on the indicator. A master gauge accompanies every finish style and size of work gauge.

Adjustment is provided for properly calibrating the

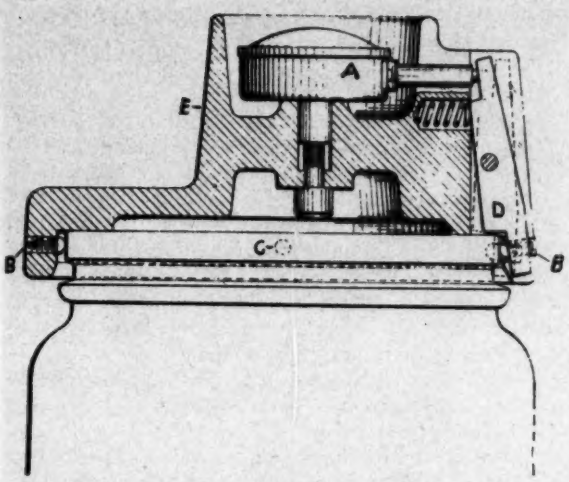

Fig. 3. A. Indicator. B. Hardened measuring points. C. Hardened Centering points. D. Trigger for activating indicator. E. Protective aluminum housing.

Finish Gauge when assembled and also to compensate for wear, through period checking.

The Hartford-Empire company states that it plans to make available the proper size of finish diameter gauge for every full set of food jar mould equipment required to operate a forming machine. The Company also states that while the gauge described in this article is for our type of vacuum finish it is expected that gauges for other vacuum finishes and a similar gauge for screw cap finishes will be available in the not too distant future, a similar gauge will soon be put on the market for screw cap finishes.

THOMAS W. ROWE OF OWENS-ILLINOIS DIES

Thomas W. Rowe, Manager of Labor Relations for the Industrial Relations Division of Owens-Illinois Glass Company, died on June 11 at the age of 76.

Mr. Rowe, at the age of 14, went to work in the plant of the Tumbler Works, Rochester, Pa., where he gained his first glass making experience. In 1891, he joined Libbey Glass Company after which he became an official of the American Flint Glass Workers Union. He was national president for 14 years.

In 1916, Mr. Rowe became affiliated with the Owens Bottle Company. He held the posts of manager of the company's Charleston, W. Va., plant and general factories manager of the American Bottle Company and the Graham Glass Company, subsidiaries of the Owens Bottle Company. When Owens Bottle Company and the Illinois Glass Company merged in 1929, Mr. Rowe took over the duties of Labor Relations Manager and continued in this position until his death.

• The annual service award and presentation to employees of the Hart Glass Division of the Armstrong Cork Company at Dunkirk, Indiana, was held recently. The award is in the form of a pin, lapel button or watch charm showing the number of years' service with the former Hart Glass Company and the Armstrong Cork Company beginning with ten years' service and at five-year intervals thereafter.

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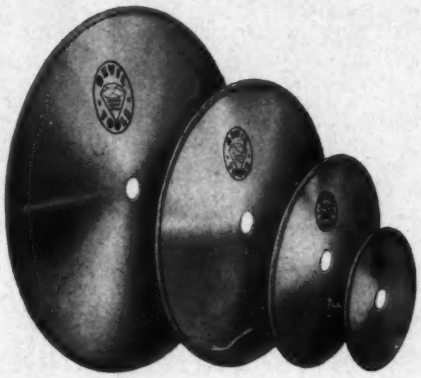

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BOOK REVIEW

"The Chemical Formulary, Vol. VII"

by Harry Bennett

The most recent volume of The Chemical Formulary, Volume VII, contains more than two thousand formulas for mixing and making products of use and interest to the general public. With the assistance of some of the country's ablest chemists from leading industries and universities, formulas covering an almost universal range of items have been collected, tested and edited. These items can be made easily and inexpensively at home, factory, shop or laboratory by students, businessmen, housewives or just plain putterers.

Each of the seven volumes published contains different material and can be used separately or as a set. Volume VII includes formulas for a long index ranging from adhesives to the various zinc solutions for rust prevention and covers the latest scientific discoveries in chemistry and industry.

Edited especially for the layman, Volume VII will be available through bookstores and by mail order to the public. Previous volumes were designed primarily for experienced chemists and technicians.

Published by The Chemical Publishing Company of Brooklyn, New York. The price is $6.00.

CORNING BUYS CANADIAN PROPERTY FOR PYREX WARE MANUFACTURE

Another step in the expansion program of Corning Glass Works was revealed recently with the announcement of the completion of negotiations for the purchase of a new plant at Leaside, Ontario, Canada. The plant will manufacture a complete line of glass baking ware, the first to be made in the Dominion. It was further stated that operations would be broadened as rapidly as possible to cover the manufacture of other types of glassware. Up until this time, Canada had been supplied with Corning products from their American plants through the distribution channels of the John A. Huston Company of Toronto.

The operations of the Canadian plant will be handled through a wholly-owned subsidiary to be established for this purpose. The new plant is a portion of the plant formerly managed by Research Enterprises, Ltd., for the manufacture of optical glass for war purposes.

The plant purchased by Corning is the mobile assembly building and, inasmuch as it was not designed for glass manufacturing, extensive reconversion work will be necessary to adapt facilities for such a purpose. It is felt that reconversion will make it possible to start production earlier than if a new plant were built.

It is expected that the production of baking ware in the plant will not commence until the Spring of 1946 at the earliest. Should unforeseen war developments necessitate the continued use of the plant for war purposes, production might not start until an even later date.

In Corning's first manufacturing venture in Canada, production will be focused entirely upon the manufacture of Pyrex brand ovenware.

• Announcement has been made that the Thatcher Manufacturing Company's plant located at Lockport, New York, has been sold to Laucks, Inc., a subsidiary of Monsanto Chemical Company. When in operation, the plant was used for the manufacture of milk bottles.

Photo by C. L. Babcock

Dr. Ross C. Purdy and M. C. Booze.

NORTHWEST OHIO SECTION OF A.C.S. HOLDS MEETING OF TIFFIN

The final meeting of a highly successful first year of the Northwestern Ohio Section of the American Ceramic Society was held June 8 at the Mohawk Golf Club at Tiffin, Ohio.

A dinner meeting in the clubhouse was presided over by A. H. Couch, Toledo, Chairman of the Section. Inasmuch as this was the first meeting held in the southern part of the Northwestern Ohio region, Chairman Couch introduced the following Section officers and organizers: Robert Twells, Fostoria, Councillor; H. H. Holscher, Toledo, Vice-Chairman; H. A. McMaster, Toledo, Secretary; A. H. Nieman, Woodville, Treasurer; D. E. Sharp, Organizing Committee. Mr. Nieman succeeds Howard Morison, who has left the Northwestern Ohio region.

After the reading of the minutes of a previous meeting, H. H. Holscher presented an outline of next season's plans as tentatively arranged by his Program Committee.

M. C. Booze, Vice-President and General Manager of Charles Taylor Sons Company, Cincinnati, presented the technical side of the program. With the assistance of E. L. Bohn, Karl Smith and E. G. Couch, Jr., this phase of the meeting included a discussion and question box on refractories, their types, properties and uses.

Meeting arrangements were handled by Mr. Twells and F. B. Carter of Tiffin, and C. B. Babcock, Toledo, took photographs of the proceedings.

OPTICAL SOCIETY OF AMERICA SCHEDULES MEETING

Announcement has been made that the Optical Society of America plans to hold its thirtieth annual meeting at the Hotel Pennsylvania, New York, N. Y., on October 18, 19 and 20.

It is impossible at this time to know whether Government regulations restricting the holding of conventions will still be in effect in October. If they are not, this annual meeting promises to be an event of unusual importance since the program will include the usual features of an annual meeting plus most of the features, and contributed papers, that were planned for the cancelled Cleveland meeting.

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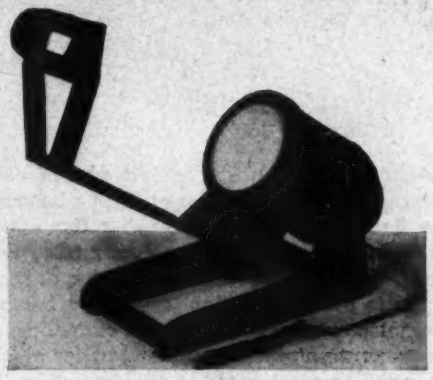

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HOW THE GLASS INDUSTRY CAN CONTRIBUTE TO EMPLOYMENT . . .

(*Continued from page* 330)

not matter so much which plan is adopted. The important thing is that a plan be adopted before the end of the Japanese war so as to take effect then—and that this plan so reduce the burden on income earned from risk-taking investment that enough investment will be encouraged to finance ten million additional jobs.

Unless that is done, new investment will be blocked, wages will be drastically cut, twenty million workers may be idle. I do not mean to say that the proper revision of our tax laws is all that is necessary to provide a high level of national prosperity after the war—but I would like to say, as emphatically as possible, that we will not and cannot have prosperity and high level employment at proper wages unless this action is taken. . . . And no group is more dependent, for its profitable operation, on its need for liberal amounts of risk capital, than the glass industry and the workers who depend upon it for a living.

NEW GLASS KILLS FLIES—EXPERTS CAN'T SAY WHY!

By accident, a Birmingham, Eng., scientist, Dr. W. M. Hampton, has discovered a glass which kills off flies like a death ray and which, it is thought, may become standard equipment in the pest-free pantries of tomorrow.

Dr. Hampton insists that he still does not know exactly why it is that light when filtered through this glass will kill flies. He explained that he started to evolve this particular kind of glass at the request of the Admiralty who required a "non-actinic" substance to protect lighter-than-air observation craft.

The result was what Dr. Hampton termed his "3A anti-fade"—a new form of rolled glass which would absorb heat rays. It had a bluish tinge, and its first test was in the window of an abattoir.

The first hot day people commented on the "eerie" coolness experienced beneath the windows fitted with "3A anti-fade." The next day many dead flies were noticed on the floors beneath the windows. The new glass is still killing flies in experiments — but none of the scientists who have examined it can explain why!

LOWRY HEADS SALES PROMOTION

It has recently been announced that C. Dean Lowry has been appointed Sales Promotion Manager of Libbey-Owens-Ford Glass Company. Mr. Lowry joined the company in 1936 as manager of the Extrudalite Division and, at the outbreak of the war, became technical advisor to the aircraft industry when the use of glass in many new forms for fighting planes was developed.

Mr. Lowry's new assignment will be to organize a field staff to assist him in working out cooperative campaigns for the sale of Libbey-Owens-Ford products.

• The Sterling Glass Plant at Lapel, Indiana, has resumed operations after a shutdown of some duration for necessary repairs. According to the management, it is expected operations will continue for some time to come.

KNOX ANNOUNCES TWO NEW PLANTS AND NEW BOTTLE MACHINE

Knox Glass Associates, Inc., has announced the incorporation of a new company under the laws of the State of Colorado, using the name Denver Glass Blottle Company. The plant, formerly operated by the E. & E. Glass Products, Inc., is being completely rehabilitated and with the addition of a suitable furnace and other necessary equipment, it is expected that glass container production will begin by September 1, 1945.

Arrangements for the construction of another plant in Denver have already been completed. After making several surveys regarding the western operation, it was decided by the Knox group to locate in the Mountain District. Distribution from Denver will not be confined to the Mountain States alone, however, but will serve the West Coast, including northern and southern California, and the Northwest area. It is felt that a number of factors, such as the abundance of natural gas, outward transportation facilities and other utility services, will make Denver an excellent area from which to operate.

With the addition of these two new plants to the Knox Glass Associates, the Knox group is now strategically located throughout the nation. Manufacture for the Southwest is provided from Palestine, Texas; the Deep South from Jackson, Mississippi; the Southeast from a plant which will be built just south of Atlanta, Georgia; the Midwest from Lincoln, Illinois; the Middle Atlantic States from Pittsburgh, Parkers Landing, Knox, Oil City, Marienville and Sheffield, Pa.; the North Atlantic Coast from Jersey City, New Jersey, and a plant at East Stroudsburg, Pa. The Atlanta and East Stroudsburg plants will be completed just as soon as war restrictions are lifted and the necessary materials are available.

Upon the completion of the present program, it is estimated that the annual sale of glass containers by the Knox group of companies will approximate thirty million dollars and approximately 4,500 persons will be employed. The plants will be so situated as to provide almost overnight truck deliveries to practically any trading center of any consequence in the United States.

Another development announced by R. R. Underwood, President of Knox Glass Associates, is the imminent completion of a continuous glass forming machine which has had an experimental period of about two years. It is contemplated that the installation will take place during June of this year. It is stated that the machine has been designed with rigidity and speed as the prime objectives and it is expected that items such as carbonated beverage and beer bottles will be produced at a speed of approximately 65 per minute without the necessity of employing multiple orifices or feeds. The new machine avoids the use of dual cavity blank and blow moulds and, in the opinion of the Knox management, lends greater versatility to the equipment. The machine, when finally placed in operation, will be made available for inspection to the industry in general.

The Knox companies, although primarily devoted to the manufacture of container ware, began to develop about three years ago a line of wholly pressed ware such as tumblers and miscellaneous flat glass. Only one furnace is operating on this type of ware at the present time. However, it is planned that additional capacity will be assigned this division in the postwar era.

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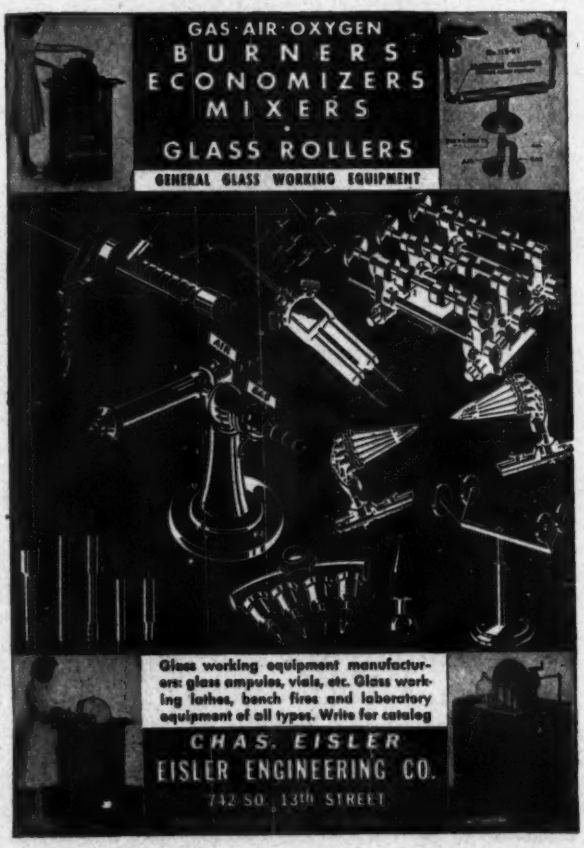
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